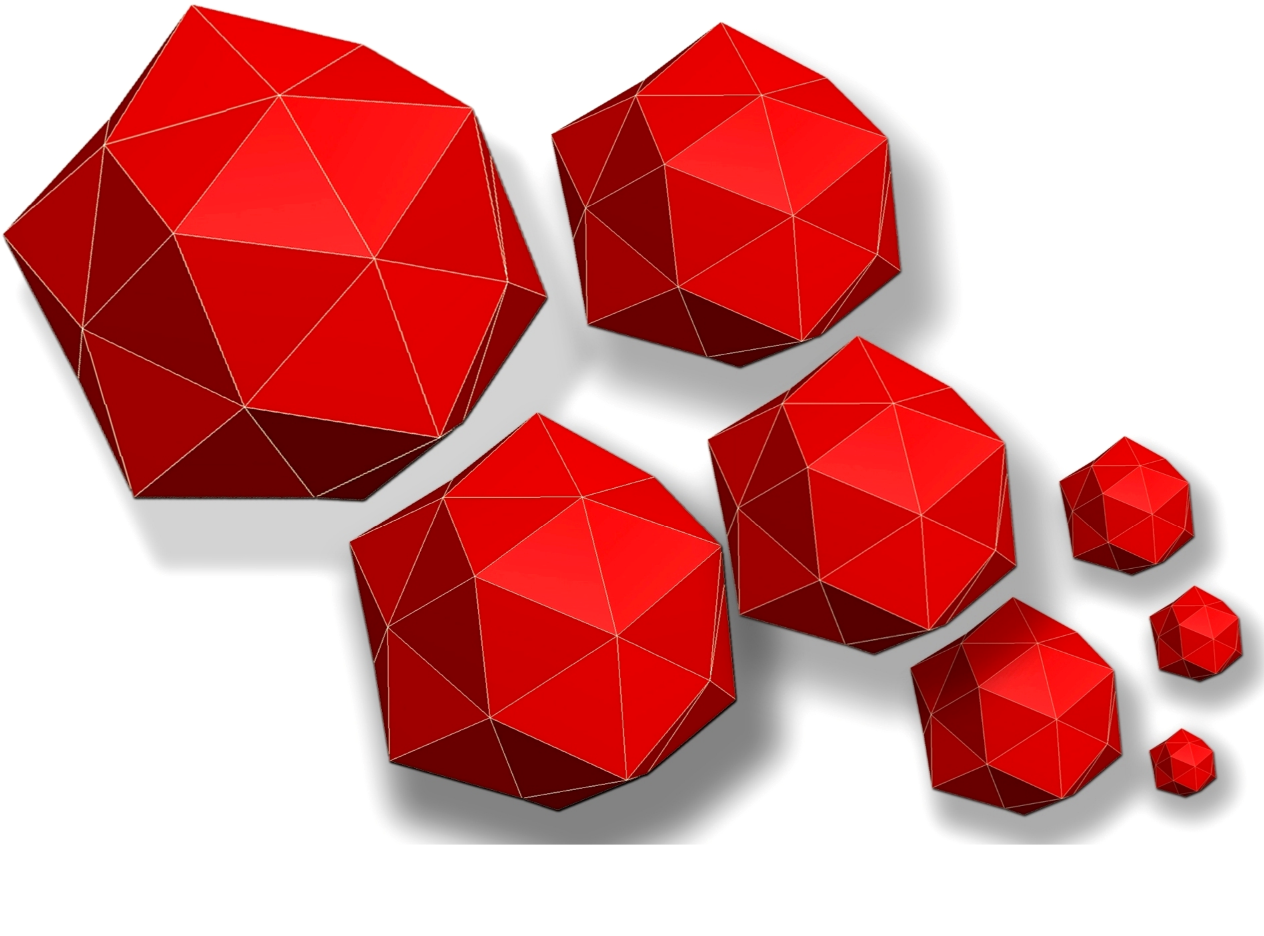
SCIENCE AND TECHNOLOGY EDUCATION: CURRENT CHALLENGES AND POSSIBLE SOLUTIONS

Proceedings of the 3rd International Baltic Symposium on Science and Technology Education (BalticSTE2019), Šiauliai, 17-20 June, 2019

Vincentas Lamanauskas (Ed.)



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THE IMPLEMENTATION OF FORMATIVE ASSESSMENT INTO CHEMISTRY EDUCATION AT SECONDARY SCHOOL

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Abstract

The results of the implementation of formative assessment into chemistry education at secondary school for the topic "Mixtures" are presented here. Students (12-14 years old, N=202) were divided into two groups – control (N=97) and experimental (N=105). Teachers of experimental group implemented formative assessment tools into ten lessons (a predictive card, Frayer model, self-assessment card, T-card, concept map, and exit card). Control group teachers taught without formative assessment. The Mann-Whitney U test confirmed statistically significant results (p<.05).
Keywords: *formative assessment, secondary school, mixtures.*

Introduction

Children´s learning is the main aim of the school. Assessment plays an inseparable role in that process (Black, 1993). Teachers use summative and formative assessment at their lessons. Michael Scriven has first used the term 'formative evaluation' in connection with the curriculum and teaching (Scriven, 1967). Bloom, Hastings, and Madaus (1971) have mentioned 'another type of evaluation which all who are involved - student, teacher, curriculum maker - would welcome because they find it so useful in helping them improve what they wish to do', which they have termed 'formative evaluation'. Such assessment becomes formative assessment when the evidence is actually used to adapt the teaching to meet student needs (Black & Wiliam, 1998). Evidence of the impact of formative assessment on students´ learning is clear and considerable (Black & Wiliam, 1998). Many studies have been devoted to assessment for learning (Zeng, Huang, Yu, & Chen, 2018). On the other side, there have been critical views on this assessment, arguing that there has been a limited body of scientifically based empirical evidence (Dunn & Mulvenon, 2009). As has been summarized in Dunn and Mulvenon, 2009, researchers have reproached the small size of experimental groups, self-selection, study without a control group.

In Slovak schools, summative assessment has the main role in students´ assessing. As has been mentioned in OECD Reviews of Evaluation and Assessment in Education in the Slovak Republic (Shewbridge, Van Bruggen, Nusche, & Wright, 2014), the idea of formative assessment is not well understood by teachers, students, and parents. Results have shown that the integration of the assessment process in a formative way (especially with inquiry) has been a difficult task (Bernard, Dudek-Różycki, & Orwat, 2019). It is probably due to the fact that teachers have difficulties with finding a balance between giving to students the leading role at the lesson and guiding them by questioning.

The main aim of this research was to find out whether there are significant differences in the results of students taught with formative assessment and students taught without formative assessment (summative assessment only).

Research Methodology

The sample consisted of 202 students from five Slovak secondary schools. Of the 202 participants, there were 75 (37.1%) young men, 80 (39.6%) young women, and 47 (23.3%) participants with missing gender information. The sample consisted of the 7th grade secondary school students. They were randomly assigned either to a control group or an experimental group. There were 105 (52%) participants in the experimental group and 97 (48%) participants in the control group.

Experimental group teachers implemented formative assessment tools into ten lessons (predictive card 3x, Frayer model 1x, self-assessment card 3x, T-card 2x, concept map 1x, and exit card 1x) into the topic "Mixtures". Teachers in the control group did not use formative assessment tools, and they taught and assessed without formative assessment. The teachers were provided with the types of tools that were applied in the evaluation process. Both groups were taught by the same teachers.

Cognitive test was given to both groups after ten lessons. The test was built in Bloom´s revised taxonomy and consisted of ten items - remember 2x, understanding 3x, apply 2x, analyze 3x (Table 1). These questions were created and evaluated by the National Institute for Certified Educational Measurements of Ministry of Education, Science, Research and Sport of Slovak Republic.

Table 1. The assignment of the test items to the Bloom´s learning domains.

Number of item	Learning Domains
1	Understand
2	Analyze
3	Analyze
4	Understand
5	Understand
6	Apply
7	Apply
8	Remember
9	Remember
10	Analyze

First, a descriptive analysis of the items was performed to calculate the mean, median and the standard deviation. A Kolmogorov Smirnov test was used in order to determine whether the sample available corresponded to a normal distribution, and then independent comparison tests were performed with a significance level of $p<.05$. The sequence of Mann-Whitney U tests was conducted to compare the results of the control and experimental group. The statistical analysis was performed in SPSS ver. 18 (SPSS Inc, 2009).

Research Results

The Mann-Whitney U test was performed for the entire test, groups of the items according to Bloom´s learning domains, and each of the items in the test separately. The results are presented in Table 2.

Table 2. Results of the Mann-Whitney *U* test.

		Experimental Group	Control Group	*p*-value				
		Mean	Median	Std. Deviation	Mean	Median	Std. Deviation	
Items separated	Item 1	.56	1.00	.499	.31	.00	.465	<.0001
	Item 2	.53	1.00	.501	.19	.00	.391	<.0001
	Item 3	.70	1.00	.458	.29	.00	.455	<.0001
	Item 4	.80	1.00	.402	.66	1.00	.476	.025
	Item 5	.87	1.00	.342	.80	1.00	.399	.231
	Item 6	.48	.00	.502	.20	.00	.399	<.0001
	Item 7	.30	.00	.458	.08	.00	.277	<.0001
	Item 8	.42	.00	.496	.43	.00	.498	.842
	Item 9	.59	1.00	.494	.14	.00	.353	<.0001
	Item 10	.05	.00	.214	.10	.00	.306	.134
Items grouped	Remember	.50	.50	.350	.29	.00	.321	<.0001
	Understand	.74	.67	.282	.59	.67	.283	<.0001
	Apply	.39	.50	.388	.14	.00	.304	<.0001
	Analyze	.43	.33	.284	.19	.00	.240	<.0001
Entire test	.53	.50	.208	.32	.31	.204	<.0001	

Results indicated the significant differences ($p<.05$) between the control and experimental groups in the entire test. Describing the individual items, results show highly significant differences for the usability score in all items except item 5 ($p=.231$), item 8 ($p=.842$), which are focused on lower order thinking skills according to Bloom´s order (remember and understand) and item 10 ($p=.134$). Highly significant results were in items aimed to remember ($Z=-4.360$, $p<.0001$), items aimed to understand ($Z=-3.895$, $p<.0001$), items aimed to apply ($Z=-5.103$, $p<.0001$), items aimed to analyze ($Z=-5.785$, $p<.0001$). Depending on the results, mean of the score of the experimental group was higher than the score of the control group in all items except item 8 (.42<.43), and item 10 (.05<.10), but it is visible that the difference was very small.

Conclusions and Implications

Because of the results of this research, it can be said that using formative assessment in chemistry education statistically improves students´ knowledge. Mann-Whitney U test finds the difference to be highly significant in items aimed to remember, items aimed to understand, items aimed to apply, and items aimed to analyze. These results are preliminary, and it is important to confirm them after a longer period and after multiple interventions. In depth analysis could provide us with the information, which elements of formative assessment have influenced the scores. This gives us a field of how we could improve the next steps.

Acknowledgments

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PRE-SERVICE CHEMISTRY TEACHERS´ BELIEFS ABOUT ARGUMENTATION AND ARGUMENTATIVE PRACTICE

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Abstract

The purpose of this research was to gain an understanding of pre-service chemistry teachers' beliefs about argumentation and argumentative practice in the context of school after they have participated in intentional argumentation training. A month after completing their training, the researchers conducted interviews with them and analyzed the responses using the content analysis method in which there are a de-contextualisation, re-contextualisation, categorization, and compilation of information. The results show that pre-service chemistry teachers´ beliefs about argumentative practice are in line with the literature of the area.
Keywords: *argumentative practice, content analysis, pre-service chemistry teachers*.

Introduction

Over the last 20 years, the relation between argumentation and science education has been attracting the attention of many researchers and a growing number of scholars is focusing on strategies for implementing argumentative tasks and analyzing their effects (Faize, Husain, & Nisar, 2018). The teacher plays a central role in engaging students in actions that enhance argumentative knowledge construction. Among other things, teachers are expected to establish and nurture argumentative discourse in class activities in order to engage students in the promotion of their argumentative skills (Archila, 2014). Pre-service training programs may need to prepare science teachers for dialogue and argumentative knowledge construction in the classroom.

In initial pre-service education, teachers can be encouraged to practice argumentation and thus, their beliefs and practices can be progressively refined. Although the teachers' professional development in argumentation practices is extremely relevant, it has not been studied in depth (Faize, Husain, & Nisar, 2018). Consequently, this research attempts to address the following question: *What are the pre-service chemistry teachers' beliefs about argumentation and argumentative practice in the school context after they have participated in intentional argumentation training?*

Research Methodology

The group of participants consisted of 6 pre-service teachers (PSTs) from a Brazilian university-University of São Paulo. They were enrolled in a Teaching Practice Course, offered in the last year of Initial Teacher Training for Chemistry. The purpose of the course was to qualify PSTs to teach chemistry at high school level. The data collection spread out over two stages. In the first stage, the PSTs participated in training to support and create an adequate argumentation environment for high school students (Lourenço, Ferreira, & Queiroz, 2016). To support the development of the PSTs´ argumentation skills, 7 sets of activities were developed in learning scenarios, to provide a suitable and stimulating learning environment, to provide instructions about the structure of argumentation, and to create an environment for PSTs to think and ask questions. These scenarios included the presentation of argumentation models, a reading workshop, and the design of chemistry argumentation lessons. The training extended over two semesters. In the second stage, semi-structured interviews were conducted with the PST. A set of questions was asked to identify their beliefs about the definitions of argumentation and the benefits of argumentation in the classroom. In this research, the interview data was explored and a content analysis method was used in which the information was analyzed in four stages: de-contextualisation, re-contextualisation, categorization, and compilation of information (Bengtsson, 2016).

Research Results

Definitions of Argumentation

Table 1 shows the results of the PSTs' beliefs about the category *definitions of argumentation*. The PSTs understand the definition of argumentation as a way to express ideas and opinions with the intention to convince. For this purpose, valid arguments are needed on a scientific base. This conception is close to the definition of literature (Ogan-Bekiroglu & Aydeniz, 2013).

Table 1. PSTs' category of perception about the definition of argumentation.

	Pre-service teacher					
Category	PST1	PST2	PST3	PST4	PST5	PST6
Argumentation is a way to express ideas and opinions with the intention of convincing using arguments validated on a scientific base.	•	•	•	•	•	•

Below is an excerpt to illustrate the beliefs of PST1 about the definition of argumentation: "*You have a point of view. You have to talk about it and defend it. In order to be more credible about what you are defending, generally you have to base your opinion on scientific concepts or experiments*". The fact that PSTs consider using a theoretical base to construct arguments corroborates with the literature that argumentative practice in the context of school should relate claims and data (Xie & So, 2012). Moreover, the PSTs' beliefs show that argumentation has a persuasive nature and affords a reasonable critic as a co-participant. Another aspect that was identified is the collaborative nature of argumentation as considered by Faize, Husain and Nisar (2018).

Benefits of Argumentation in Science Education

The category *Benefits of argumentation* compiled the beliefs of the PSTs about the benefits of the practice of argumentation in the school context. The PSTs' beliefs are separated into these two types of tasks: *Arguing to learn* and *Learning to argue* (Table 2). The division was based on the work of Walker and Sampson (2013) "students need to engage in argumentation in order to develop a better understanding of the content (i.e., arguing to learn) but also students need to learn what counts as an argument and argumentation in science (i.e., learning to argue) as part of the process" (p. 592) [emphasis added].

Table 2. PSTs' subcategories of beliefs regarding the benefits of argumentation in the classroom.

		Pre-service teacher					
	Category	PST1	PST2	PST3	PST4	PST5	PST6
Arguing to learn	Help the students' learning of scientific concepts	•	•	•	•	•	•
	Help students to correlate scientific concepts in everyday contexts	•		•	•	•	
	Allow students to formulate scientific hypotheses	•	•	•		•	•
	Help students to learn how to build scientific arguments	•	•	•	•	•	•
	Allow students to solve scientific problems			•	•		
	Allow students to relate scientific concepts	•		•	•		
	Help in the evaluation process of students' scientific knowledge	•		•		•	•
Learning to argue	Develop the students' critical thinking	•		•	•	•	
	Allow students to play a more conscious role in society	•	•		•	•	
	Help students defend their own point of views	•	•	•	•	•	•
	Help master scientific language				•	•	
	Help students to evaluate an argument	•				•	

In *Arguing to learn*, the subcategories identified for all PSTs are *Help the students' learning of scientific concepts* and *Help students to learn how to construct scientific arguments*. In relation to the first subcategory, the PSTs pointed out the importance of argumentation to support the student's understanding of scientific concepts, laws and theories. Below an excerpt illustrates PST4's perception that shows that engaging in argumentation discourse is an effective way for students' learning. "*If one has to talk about something, defend a point of view, form an opinion or decide something, one has to have some knowledge to do so in order to assimilate the content better*".

The other subcategory with high frequency was *Allow students to formulate scientific hypotheses*. In relation to this aspect, existing research points out that prior knowledge influences the process of learning. Here is a part of speech of the PST3 which falls into this subcategory: "*So, when you say what you are thinking, you start to formulate hypotheses, opinions about the subject that perhaps you did not even believe you had, so, I think that if something is well done, it is great and encourages learning*". PSTs also pointed out how argumentation contributes to students relating concepts discussed in the school context to everyday aspects. This benefit is represented in the subcategory *Help students to correlate scientific concepts to everyday contexts* and illustrated in the following excerpt. "*The fact that the activity is related to everyday aspects ... attracts many students who usually do not pay much attention in the classroom, and it stimulates reflexion and decision taking*". PSTs also noted that they could obtain feedback on students' understanding beyond exam periods, i.e. dialogue in the classroom served as a means of continued evaluation of the learning progress (see category "*Help the evaluation process of scientific knowledge of students*").

In *Learning to argue,* the identified subcategory for all PSTs was *Help students defend their own point of views*. This category points out that the argumentative practice in the context of school helps the students to defend their ideas while developing the elements of their arguments. For example, in the following transcript, PST3 identifies elements of a persuasive argument: "*In an argumentative activity you know that you have to expect hypotheses, draw conclusions, justify your opinion, face rebuttal and defend your point of view*" PST3. Another category that stands out is *Develop the students' critical thinking.* The ability of critical thinking helps the student to become a citizen who is capable of participating actively, for example, in socio-scientific topics and scientific dialogs. This ability involves the category *Allow students to play a more conscious role in society.* The following excerpt illustrates the perceptions of the PST1 in this area: "*The students really learn, they have their own opinion... develop their critical sense ... They act more in society and thus become a real citizen*".

Conclusions and Implications

This research sought to gain an understanding of PSTs' beliefs about argumentation and argumentative practice in the context of school after they have participated in intentional argumentation training. The PSTs' beliefs were identified concerning the definition of argumentation and the benefits of using argumentation in science education, learning to argue and arguing to learn, are close to the ones we find in the literature. The importance of training in the refined belief of the PSTs can be pointed out. It can be considered that the approximation of the PSTs' beliefs of our research with the literature is a way for PSTs to implement the argumentation in their future teaching practice in chemistry teaching.

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MULTIPLE REPRESENTATIONS IN DEVELOPMENT OF STUDENTS' COGNITIVE STRUCTURES ABOUT THE SAPONIFICATION REACTION

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Abstract

The purpose of this research was to know what the effect of the use of multiple representations (MR) was in the development of the students' cognitive structures. This research was conducted in three Grade 12 classes, in a total of 68 students. A Word Association Test (WAT) was used as data collection instrument. The results from WAT show that students' cognitive structures progressed from pre-test to pos-test, with an increase in the number of response words and connections between words.
Keywords: *multiple representations, cognitive structures, word association test, saponification reaction.*

Introduction

Conceptual understanding in Chemistry requires observing phenomena at three levels: macroscopic (e.g., seeing and manipulating objects, experimenting with and describing the properties of materials); submicroscopic (e.g., understanding and explaining observations in terms of non-visible and abstract objects such as atoms, ions and molecules); and symbolic (e.g., translating the understanding of observations through chemical equations, analogies and model kits) (Johnstone, 1982). Studies have emphasized that combining these three levels is essential for effectively learn Chemistry (e.g., Talanquer, 2011). However, students have difficulties in moving from the macroscopic level to the symbolic and submicroscopic levels (Prain, Tytler, & Peterson, 2009). This movement implies that students must develop their logical and abstract thinking skills, as well as their cognitive structures, that involve connections between terms, concepts and process (Derman & Eilks, 2016).

In this sense, considering the importance of students being fluent in all three levels of Chemistry (macroscopic, submicroscopic, and symbolic), it is essential to use various learning resources that help them move between these representational levels. The use of representations has been pointed out by several researchers as one of the facilitators for explaining phenomena in Chemistry, enhancing students' conceptual comprehension (e.g., Ainsworth, 1999; Gilbert, 2008). The use of two or more representations, when studying a concept is considered as learning with multiple representations (MR) (Tsai & Treagust, 2013). MR have a fundamental role in understanding concepts and the relationships between them (Gilbert & Treagust, 2009; Tsai & Treagust, 2013), which implies the development of students' cognitive structures, and as a field of research in education that has been gaining relevancy. Although most research indicate that the use of MR favors students' conceptual learning in Chemistry, there still aren't many studies concerning how MR influence the development of students' cognitive structures. This research intended to contribute to the increase of knowledge in this area. The following research questions guided this research: what is the effect of the use of MR in the development of students' cognitive structures about saponification reaction?

Research Methodology

This research followed a pre-experimental one group pre-test-post-test design, providing an intervention during the experiment (Creswell, 2002). This design facilitates the comparison of students' cognitive structures change, before (moment 1) and after (moment 2) a sequence of lessons on saponification reaction, using MR. This research was conducted in three Grade 12 classes, including a total of 68 students (36 = 57% female and 32 = 43% male; age range 17-19) who attended a school in the Lisbon metropolitan area in Portugal. Students belonged to the upper-middle class. In the 12th grade Chemistry curriculum, one of the topics is again Organic Chemistry, in which students encounter concepts such as acyclic and cyclic aliphatic hydrocarbons, aromatic hydrocarbons, functional groups and chemical reactions between organic compounds, among others. This research was focused on a chemical reaction, the saponification reaction. The three classes on the saponification reaction (total duration 360 minutes) were taught by three Chemistry teachers. Each teacher conducted the lessons in their class using MR, such as video, laboratory material, models kits and chemical equations. In this research a Word Association Test (WAT) was used as data collection instrument. The Word Association Tests (WAT) was developed by Johnson (1967, 1969). In WAT implementation, the researcher or educator selects relevant concepts (stimulus word) and asks students to write words associated with these concepts (response words) in a certain period of time (Nakiboglu, 2008). According to Bahar, Johnston and Sutcliffe (1999), WAT are considered as a "snapshot" of the students, since they do not have the time to prepare themselves and thus what is visible is the "raw state" of their cognitive structure. Through the quantity and quality of the associated words, the understanding of the concept can then be evaluated. The WAT was applied in two moments of the research - moment 1/pre-test (M1): three weeks before lesson 1; moment 2/post-test (M2): three weeks after lesson 3. To stimulate the association of words, four words were given to the students, each on a separate blank sheet: ester, alcohol, soap and basic solution. The WAT data analysis was performed based on the response frequencies map method (Nakigoblu, 2008). It began by analyzing the terms associated with the stimulus words. Words that were "meaningful", i.e., the response words of the students related to the saponification reaction were counted and validated as response words. The frequency table was constructed by placing the stimulus words in the first row, in the second row the pre-test (M1) and post-test (M2) moments, and the response words were placed in the first column. In addition to the frequency table, we constructed a table illustrating the number of different responses to a given stimulus word at the two moments (Derman & Eilks, 2016). The number of different responses to a word is a direct indication of the "meaningfulness of the key concept" and a word without associations has no meaning (Bahar et al, 1999).

Taking in account the data presented in the frequencies tables, the students' cognitive structures maps were constructed at moments M1 and M2. In order to distinguish the nature of the connections that students establish between words, a qualitative analysis of the sentences written by the students was performed, allowing us to include examples of answers for each of the frequency intervals.

Research Results

In order to examine the effect of a sequence of lessons on saponification reaction using MR in the development of students' cognitive structures, a table of frequencies (Table 1) was built, which indicated the number of response words per stimulus word at two different moments: M1 (pre-test) and M2 (pos-test). The data presented in Table 1 were used to construct the maps of the students' cognitive structures for each moment: M1 (Figure 1) and M2 (Figure 2).

Table 1. WAT frequencies table at pre-test (M1) and post-test (M2).

	Stimulus words							
	Ester		**Alcohol**		**Soap**		**Basic solution**	
Response words	M1	M2	M1	M2	M1	M2	M1	M2
Ester				28	3	66		34
Alcohol		32			1	33		16
Soap	2	67		43				65
Basic solution		42		26	26	62		
Polar					51	56		
Non-polar					52	54		
Solute							61	63
Solvent			57	33			62	65
Micelle					16	37		
Fat		43		8	65	67		9
Carbon chain	32	24	36	22		26		
Hydroxyl group		12	51	52	17	45	47	52
Carboxylic acid	24	32						
Glycerol		17		38		18		12
Hydrolysis		3				21		17
Chemical transformation		14			5	8		14
Bond break		6				9		
Saponification		4				13		
Nucleophile								5

In Figure 1, at the strongest association level of students' cognitive structures, between $61 \leq f \leq 70$ frequency range (Level 4), only two stimulus words- "soap" and "basic solution"- appeared. "Soap" was associated to only one response word, "fat", and "basic solution" was associated to two response words: "solute" and "solvent". Some excerpts of the students' phrases for this frequency range revealed the nature of the connections: "soap is used to remove fat"; "in a basic solution, the solvent is water and the solute can be sodium hydroxide". These examples showed that, at M1, students related soap to fat removal and that only two of the students identified fat as reactant in soap production. At level 3 ($51 \leq f \leq 60$), the word "soap" was also associated to two new response words: "polar" and "non-polar". Also, at this level occured the stimulus word "alcohol", to which students coupled two response words: "hydroxyl group" and "solvent". The stimulus words "alcohol" and "basic solution" were connected to each other via the response word "solvent". Some of the sentences written by the students were: "the soap has a polar end and a non-polar end"; "the functional group of alcohols is the hydroxyl group"; "alcohol is the solvent in an alcoholic solution". From these examples, it can be inferred that most students associated alcohol to the solvent in an alcoholic solution, but not as a product of the saponification reaction. At level 2 ($41 \leq f \leq 50$), a new association appeared between the stimulus word "basic solution" and the response word "hydroxyl group", which was represented by the thinner arrow in this cell. At the frequency range $31 \leq f \leq 40$ (Level 1) the stimulus word "ester" appeared for the first time and it was connected to the word "carbon chain", which, in turn was also linked to the stimulus word "alcohol". The cognitive structure of students at the post-test (M2) is presented in Figure 2 and it is clear that, when compared to the one at the pre-test (Figure 1), it has more stimulus words per frequency level and that all the stimulus words are connected. Accordingly, at level 2 ($61 \leq f \leq 70$), which was the strongest level association of students' cognitive structure, three of the four stimulus words appeared interconnected, forming a network with the stimulus words "ester" and "soap", strongly associated. The association between "soap" and "basic solution" was not so strong. Another strong association, which was also present at M1, was among the stimulus word "soap" and the response word "fat". Finally, it was observed the association between "basic solution" and the response words "solute" and "solvent" that was also present at M1. Furthermore, a qualitative analysis of the students' phrases showed that the nature of the connections at M2 was related to the saponification reaction. For instance, it was stated that "in order to obtain soap we have to break a fat (olive oil), which is an ester, and add a basic solution (NaOH)"; "soap is formed from an ester (a fat), with a basic solution, in which the solvent is water and the solute is sodium hydroxide". The other level, level 1 ($51 \leq f \leq 60$), was characterized by the presence of all stimulus words whereas at M1, this only happened at the frequency range between $31 \leq f \leq 40$.

Conclusions

Effective student understanding of the saponification reaction entails their ability to explain it, by making use of multiple knowledge representations at the three levels: macroscopic, symbolic and submicroscopic. However, to enable students to move across these three levels, it is crucial that the teaching strategies used facilitate the development of their cognitive structures. In the present study, the strategies applied during the teaching using MR (video, laboratory materials, photographs, kit models and chemical equations) assisted that development. In fact, data from WAT shows that students' cognitive structures progressed from M1 to M2, with an increase in the number of response words and connections between words, and with a change in the nature of these connections.

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PILOTING MULTIDISCIPLINARY FIELDWORK PROJECT "FOREST"

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Abstract

In Latvia, a new curriculum is introduced to provide the opportunity to acquire skills in multidisciplinary context. To achieve that, schools need to implement projects. In this paper, one example of a multidisciplinary project where fieldwork is involved is described. The aim of the research was to create support materials for teachers and students based on practice to experience multidisciplinary fieldwork to develop competencies. In the end, thirteen different support materials for teachers and students were piloted.
Keywords: *multidisciplinary fieldwork, fieldwork project, school practice*.

Introduction

Starting in 2016, the project "Competency based Curriculum Development and Implementation in Education" started its activities, aiming at ensuring the piloting of the new curriculum of competency-based learning in accordance with the compulsory description of general education and introduction of the curriculum in pre-school, primary and secondary education. The reform of the curriculum that has been initiated is a continuation of the further development of the guidelines formulated in the curriculum for development of competences including fieldwork (LR MK, 2016).

New curriculum materials are being developed and piloted to provide the opportunity to acquire skills in a multidisciplinary context. In this paper, one of the examples of multidisciplinary project where fieldwork is involved is described. The aim of the research was to create support materials for teachers and students based on practice to experience multidisciplinary fieldwork to develop competencies.

Fieldwork, which can be defined as any curriculum component that involves leaving the classroom and engaging in teaching and learning activities through first-hand experience of phenomena (Boyle, Maguire, Martin, Milsom, Nash, Rawlinson, Turner, Wurthmann, & Conchie, 2007), has not a long range of examples in Latvian geography or biology subjects across the 14-19 age range. Also, before curriculum reform that was not mandatory for schools to implement (LR MK, 2006). This is despite the fact that it has long been known that well-conducted fieldwork can make a tremendous difference to the learning and motivation of studying, raise motivation, reduce anxiety about learning and encourage deeper rather than more surface approaches to learning (Amos & Reiss, 2012; Lambert & Reiss, 2016; Fisher, 2001).

Through fieldwork with authentic situation, student develops problem solving skills, critical thinking, attitudes, values, scientific literacy. This is one of the best ways to achieve competencies in sciences because it combines many skills and ends with student competencies. There is abundant evidence to show that fieldwork is highly rated by students (Lambert & Reiss, 2016). A similar situation is happening in other countries (Fisher, 2001; Lambert & Reiss, 2016). Especially for these reasons, there is a need for good fieldwork examples for teachers to implement with their classes.

Research question: What are the benefits and risks for students and teachers in terms of content development according to the plan?

Research Methodology

To design the curriculum and materials, the research group worked for curriculum reform and noticed that biology and geography subjects needed an authentic problem situation where students could experience multidisciplinary fieldwork, a project where science fields merged together. To adapt the project for better implementation, the research group consulted and met professional forest rangers (Joint Stock Company "Latvia's State Forests" (LVM)) to formulate the problem situation, validate fieldwork methods, discuss needed forest polygons. Based on consultations with experts, our research team made the first base of support materials (detailed problem situation, instructions, visuals, for teachers and students). In 2018, from 6th May till 9th August the support materials for teachers and students were made.

Next phase was to use materials in practice. On 8th August 2018, a feedback from 73 teachers was collected through three questions: 1) What is good in materials? 2) What kind of questions appeared? 3) What needs improvement? Teachers admitted that this fieldwork example was a needed concept, it involved many subjects, was easily adaptable to classes, could reach needed main goals in subjects and showed fieldwork scientific methods. Teachers in process asked for detailed instructions step by step, a short video about methods, worksheets for students, evaluation examples and visuals of strategies used. Research team adapted materials for that and made needed support materials.

From 8th September till 15th November 2018, materials were adapted and piloted in two forest polygons - two schools, 48 students, 3 material authors were involved. After that in total 6 workshops, 5 presentations, one webinar was held for project popularization and to receive a feedback from more than 236 teachers about made support materials. From March to May 2019, five schools, twelve teachers, 156 students approbated support materials in three different forest polygons. Material authors advised them and collected feedback about what they gained and what needs to be improved.

Research Results

For the chosen fieldwork students needed to find explanation for a problem situation where two forests were landed in the same year, but human economic activity was different. In the end support materials were based on research question - how human economic activity affects forest stands wood stock, diversity of organisms and abiotic factors? All together different subjects were combined where specific knowledge and skills were developed, including the use of Geographical Information System (GIS) (see Figure 1).

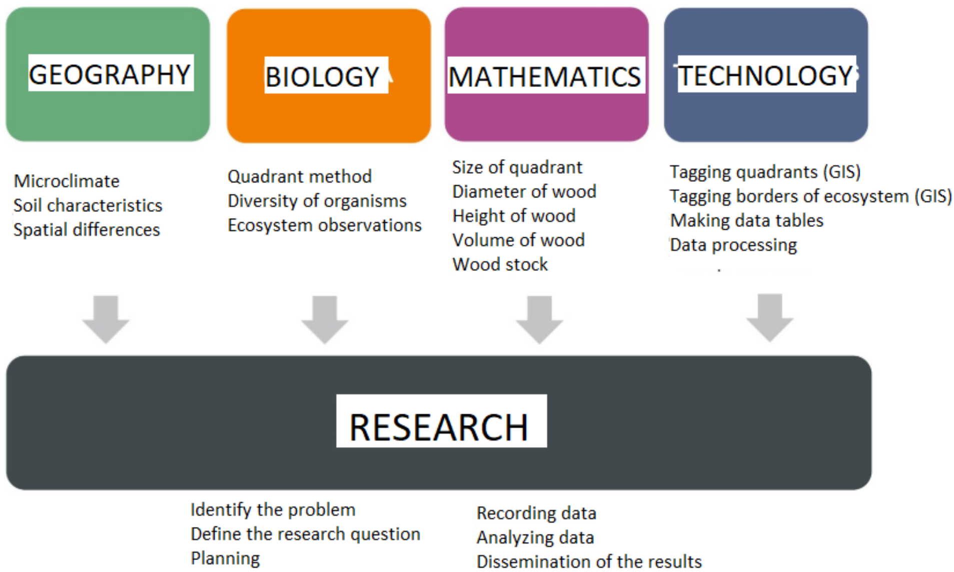

Figure 1. Fieldwork organization model and students' learning goals.

After every school practice feedback was collected from teachers and students, support materials were improved to be shorter and more visual. All together teachers needed a big support and step by step instructions about planning, implementing and analyzing phases. Based on that research group decided to make also an instructional video about used methods. The result is a collection of support materials for teachers and students to achieve complex goals through implementing multidisciplinary project in schools (see Table 1). These materials are based on practice and approbation, so they are safe to use.

Teachers acknowledged that this kind of fieldwork example is really needed especially for 14-19 age range. Also, teachers recognized risks why not to do it: money for transport, time to implement fieldwork, school support, professional knowledge about fieldworks. Similar situation and risks about project implementation are described in other countries (Lambert & Reiss, 2016). 96% of student answers correspond with research group proposed learning goals (see Figure 1).

Table 1. A list of made and adapted support materials for teachers and students.

For teachers	For students
The link between the research and the curriculum; Research steps; Example of a common theme planning; Conditions of research work; Output materials (GIS, forest stand history); Fieldwork description; Resource List; Instructional video.	Topic outline - to guide your learning; Reminders and strategies (soil profile drawing, research steps, quadrant method); Planning worksheets; Output materials (GIS, forest stand history); Evaluation rubrics for self-assessment (geography, biology, research, presentation skills, planning, data analyzing).

Student reflections showed that they found out more about different professions and scientific methods. They concluded that they saw connection between different science fields and how transversal skills were needed in different areas, that project raised their motivation to find out more about work in natural sciences. Other researchers have similar student responses (Lambert & Reiss, 2016).

Conclusions and Implications

This project provides an authentic, complex problem situation, which is a needed example for teachers to implement in schools in order to achieve newly designed curriculum learning goals.

Teachers need structured and detailed support about fieldwork methods – how to precisely measure woods stock and to do quadrant method, which are widely used in geography and biology. Our developed materials are detailed enough to achieve that.

Students concluded that this experience raised their motivation to learn, showed them connection between different science fields and how transversal skills are needed in different areas.

Acknowledgments

This project is done with Joint Stock Company "Latvia's State Forests" (LVM) support, they provided professional consultations and forest polygons for project realization. Curriculum, support materials for teachers and students are made within project Nr. 8.3.1.1/16/I/002, "Competency based Curriculum Development and Implementation in Education", Skola 2030.

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TEACHERS' VIEW ON THE LOWER SECONDARY CHEMISTRY CURRICULUM IN THE CZECH REPUBLIC

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Abstract

The research was focused on the teacher's opinions about the key and critical points of the lower secondary chemistry curriculum in the Czech Republic. Through the interviews with 40 chemistry teachers from four Czech regions was gained information about what teachers named as critical topics and what as key topics in early chemistry school contents. Some problems were identified mainly with cognition overload of learners and the necessity to realize stronger connections to everyday life and forming science literacy.
Keywords: *chemistry teachers' opinions, early chemistry education, key points of the curriculum, critical points of the curriculum.*

Introduction

Chemistry is still among the most difficult and least popular subjects taught on the lower secondary school, despite some positive progress in recent years (Grecmanova & Dopita, 2007; Höffer & Svoboda, 2005). The nature of the subject itself, i.e. the natural science orientation of the subject matter with a considerable degree of abstraction, supported by the application of mathematical rules, makes it difficult for learners of this age category. Not only the causes of this problem are sought, but also the paths leading to increasing interest in the issue of this discipline and thus improving the results in teaching. In the chemical section of the OP RDE (Operational Programme Research, Development and Education) project "Didactics: Man and Nature A" (Vocadlova & Mentlik, 2018) has been focusing on identifying the critical and key points of the curriculum in the early chemistry curriculum on the lower secondary school (Bilek, Rychtera, & Chroustova, 2017; Rychtera et al., 2018). Semi-structured interviews with a total of forty collaborating chemistry teachers from lower secondary schools and equal classes from comprehensive schools have been carried out by the subject didacticians (teacher educators) from all universities involved in the project during 2017 and 2018. The questions of the interview have focused on finding out the attitudes and experiences of teachers with the teaching of individual topics according to the FEP BE (Framework Educational Programme Basic Education) (MŠMT, 2017), i.e. which places they perceive mainly as critical and key (Rychtera et al., 2018).

Research Methodology

The main research method was semi-structured interviews (recorded as audio samples) with chemistry teachers and comparison of collected data to the analysis of the subject curriculum in relevant educational national and international documents. Single items of the semi-structured interview focused on identification of concrete conditions of teacher work, their opinions on learning content and context of instruction, and other relating aspects, e.g. textbooks used, laboratory equipment, co-operation with companies and non-educational institutions etc. The research sample in part of chemistry consisted of 40 teachers from lower secondary schools. Data were analysed by method of content analysis through frequency of occurrence.

Research Results

As part of the analysis of the audio recordings of the interviews, we found that the most critical topics for teachers were atomic structure, Oxidation state, acid nomenclature, salt nomenclature, chemical reactions, chemical equations (their notation, enumeration and calculations from chemical equations), and various chemical calculations. e.g., solution composition calculations. The frequency of identifying critical points of early chemistry curriculum (first year of chemistry teaching on the lower secondary school) is shown in Table 1 and the key points in Table 2. In particular, interestingness is the fact that teachers have identified a total of 65 critical points (284 different statements) and 91 key points (324 different statements) of the first year of chemistry teaching on the lower secondary school. In other words, almost the whole curriculum in the eyes of different teachers can be seen as both critical and key. Nevertheless, our assumptions were largely confirmed that the critical points are, in particular, topics related to a high degree of abstraction and the necessity of using mathematical apparatus. As a rule, critical points are also determined to be also key points, so their simple elimination from the curriculum is not possible (see Table 3).

Table 1. Critical points in early chemistry curriculum (first year of chemistry teaching on the lower secondary school) identified on the basis of interviews with teachers (*n* = 40).

Identified critical point (7 topics with a frequency higher than 9)	Identified frequency
Chemical equations	77
Chemical nomenclature	66
Chemical calculations	47
Matter structure	27
Chemical reaction	21
Chemical bonding	10
Chemical technology	9

Table 2. Key points in early chemistry curriculum (first year of chemistry teaching on the lower secondary school) identified on the basis of interviews with teachers (*n* = 40).

Identified key point (10 topics with a frequency higher than 10)	Identified frequency
Chemical nomenclature	59
Chemical substances and their properties	51
Chemical calculations	46
Matter structure	45
Periodic system	34
Chemical equations	24
Chemical technology	24
Safety of work	16
Chemical bonding	16
Chemical reactions	10

Table 3. Comparison of critical and key points in Early Chemistry Curriculum (first year of chemistry teaching on the lower secondary school) identified on the basis of interviews with teachers (*n* = 40); the same critical and key points are marked in bold.

Critical points		Key points	
Topic	Frequency	Topic	Frequency
Chemical equations	77	Chemical nomenclature	59
Chemical nomenclature	66	Chemical substances and their properties	51
Chemical calculations	47	Chemical calculations	46
Matter structure	27	Matter structure	45
Chemical reaction	21	Periodic system	34
Chemical bonding	10	Chemical equations	24
Chemical technology	9	Chemical technology	24

Based on the analysis of the most frequent critical as well as key points of the early chemistry curriculum, modules were created to improve their teaching and action research was used to evaluate them – see Table 4. Modules serve as a basis for revision and eventual modification of teacher teaching preparation and subsequent verification in the teaching of the subject (according to the form of the particular curriculum of the schools). In collaboration of teachers with subject didacticians, the modules are continuously modified according to the gained experience to include the optimal presentation, practice and evaluation of the subject matter of the topic.

Table 4. Topics of selected modules for innovation of Early Chemistry Curriculum.

Acids Nomenclature
Salts Nomenclature
Oxidation Number
Solution Composition Calculations
Atom Building
Chemical Reactions
Chemical Equations, Writing and Enumeration
Calculation from Chemical Equations

Conclusions

The above-presented results of the research project, having the ambition to substantially contribute to the innovation in teaching the early chemistry contents and contexts at the lower secondary school in the Czech Republic. The main emphasis has been paid on the cooperation of researchers with teachers from the practice and building so-called “teacher practice community”.

The proposed procedures for innovation of the early chemistry curriculum reflect most of the parameters of the accomplished didactic analyses. Their main contribution is a wide discussion of both topics with the aim of simplifying and making available the presented curriculum as much as possible based on the experience of subject didacticians and experience gained from lower secondary school teachers. The criticalness of the eight selected topics is directly related to the learners' intellectual maturity since these are mostly very abstract themes. Therefore, a combination of them with examples of objects and activities that learners encounter or can meet both in school and especially in everyday life is appropriate.

The initial results of action research focus on validation and evaluation of the modules of innovated topics by teachers demonstrate that methodological approaches by teachers are very heterogeneous, and it is, therefore, good to unify them to some extent, for example through jointly proposed approaches. The teachers involved in the validation confirm that the learners have acquired knowledge and skill better than in their previous lessons and it can, therefore, be assumed that the basic theses of the modules are gradually confirmed.

It is necessary to realize that it is not appropriate to perceive any topic as an isolated thematic whole, but that it permeates another curriculum of chemistry. That is why it is necessary to give the learners sufficient time to fix and acquire concrete experience for the real learning of the curriculum. It has also been shown that learners need a higher degree of activation through laboratory activities, educational games and practice. It is therefore not necessary at all costs to continue to significantly reduce the content or to look for a new revolutionary way of exposing the given topics to learners, but rather to change the approach to existing practices focusing on greater learners’ activity and sufficient time to practice the subject matter.

Acknowledgement

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CHANGES ALL AROUND US AND WITHIN SCIENCE EDUCATION

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Abstract

This work is formed as a set of thematic mind maps for presentation during authors' speech and further discussion during symposium BalticSTE2019. Selected mind maps are large-scale philosophy and psychology- based maps for general orientation within the complex situations when we are searching for definite solutions of concrete particular problems. All mind maps present visualization of definite thoughts' arrangement within corresponding structures, what are well-known products of systemic organization of humans' thinking.
Keywords: *general science education, philosophy of Science, systems theory.*

Human and Universe

UNIVERSE MEANS TOTALITY OF EVERYTHING, and everything as a part of the Universe is reflected within Human's World of Thoughts as a corresponding SYSTEM - the whole, what contains interconnected parts and what at the same time is a part of some other system. All systems are characterized by their properties, what are also characteristics of corresponding things or bodies of the Universe (Figure 1).

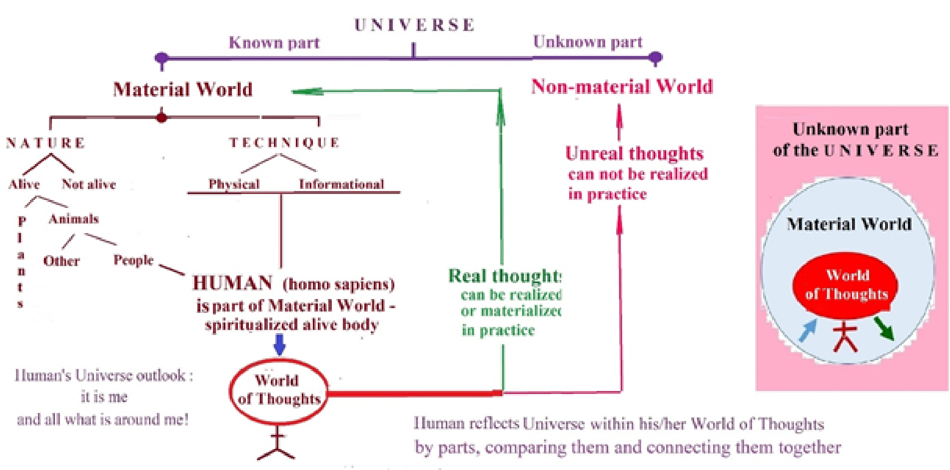

Figure 1. Human as part of the Universe and Universe within humans' world of thoughts.

Wide diversity of CHANGES is a fundamental property of everything – everything (all parts of the Universe and all systems as correspodnding reflections of these parts within human's World of Thougts) is changing (Figure 2).

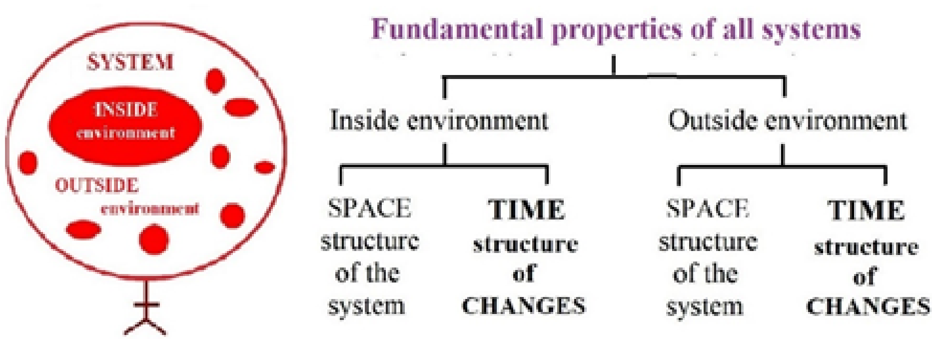

Figure 2. Human's life is a lifelong change – let us stop for a moment and think about this fact!

Short Introduction to Systemology of Changes

Following basic principles of systems approach, all changes are properties of corresponding systems as reflections of the Universe within our World of Thoughts. We are vitally interested in changes because *our life means realization of appropriate changes*. There are quantitative and qualitative changes. Understanding (factology) and comprehension (causality) of different changes are significant needs for humans' successful living (Figure 3).

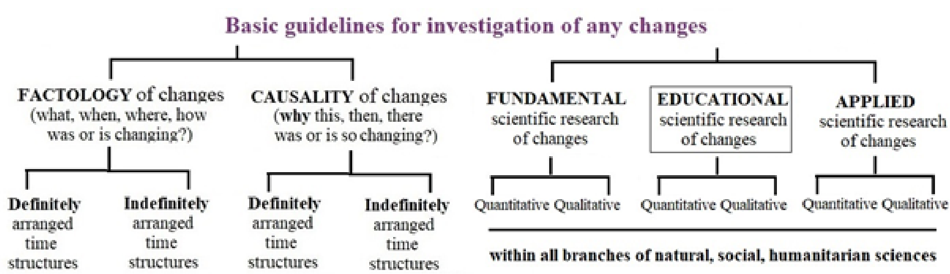

Figure 3. Above all - factology and causality of 'definite and indefinite changes.

Investigation of any change at the level of factology is described by a changing state of a corresponding property "a" according to states "t" of selected clock as timer. Using mathematics, it means making graph of appropriate function a(t). All changes as appropriate time structures are built systematically step by step, what means integration of differential parts of change within total change as the whole. Fundamental characteristic of all changes is speed (Figure 4).

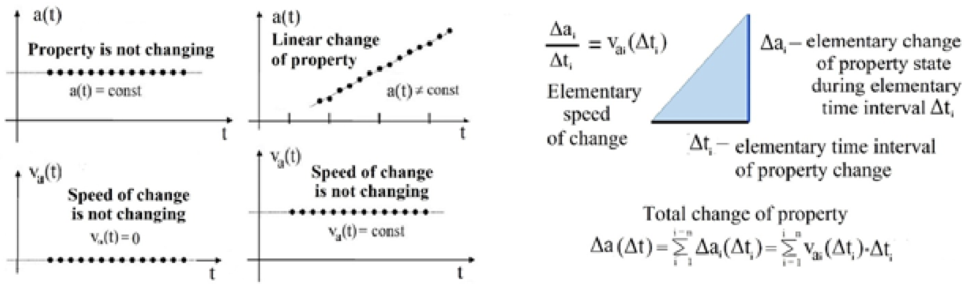

Figure 4. Graphs of simplest changes and elementary differential parts of changes.

Human's Life Activities Are Corresponding Changes

Significant part of human's life activities are purposeful changes what are organized and managed by human's thoughts and follow corresponding universal structure (Figure 5, Figure 6).

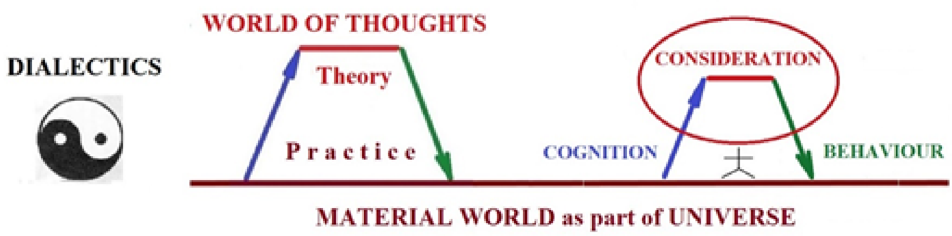

Figure 5. Cognition – consideration – behaviour are basic parts of purposeful human's life activities.

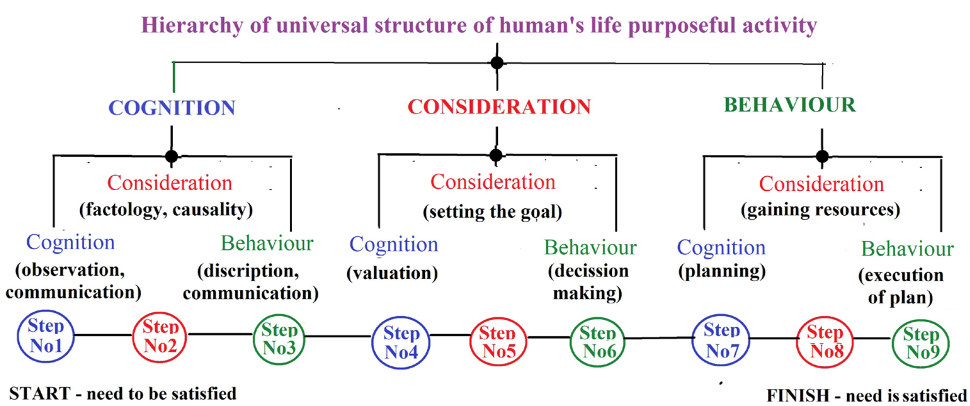

Figure 6. Nine steps within three level hierarchical structure of human's purposeful life activity.

Along with the given above content oriented structure of changes it is important to consider also general functional (Management and Execution) structure of changes (Figure 7).

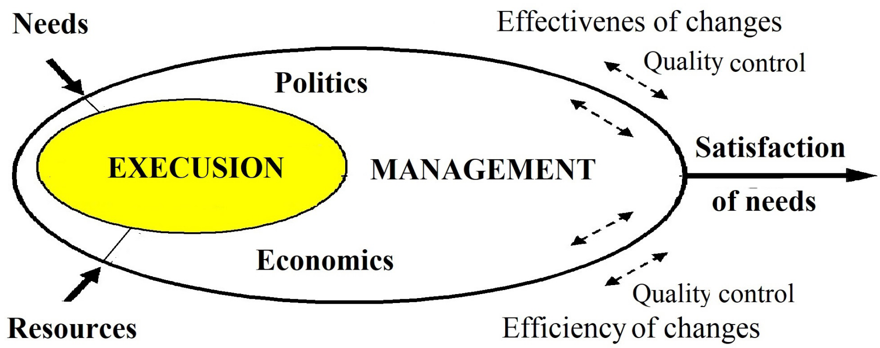

Figure 7. Functional structure of human's purposeful life activities.

Education as Purposeful Gaining of Life Experience for Life

Concepts of Life and Education as Life experience for life and corresponding changes within Life and Education always are closely interconnected. It seems to be obvious, but educational activities very often are far from real needs of different persons and societies. Be the way, effective educational activities follow the mentioned above fundamental structures of purposeful human's life activities (Figure 8).

	COGNITON	CONSIDERATION	BEHAVIOUR
SKILLS		Valuation	From theory to paractice
ATTITUDES		Selection of VALUES	
KNOWLEDGE	From practice to theory	Values	

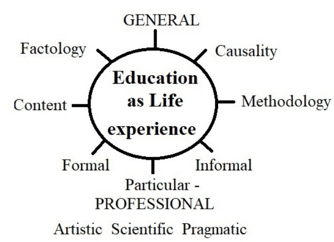

Figure 8. Systemic interconnection of LIFE activities (cognition, consideration, behaviour) and EDUCATION as life experience for life (cognition, consideration, behaviour).

Solving Problems of Interconnected Changes within Our Life and Education

Life and Education today are seriously changing. Because of the great progress of modern sciences and technologies, global explosion of information is one of the basic causes of recent overall changes.

Modern changes are high-speed qualitative and probabilistic social changes and because of that, many unexpected situations appeared. It is very difficult to predict detailed development of everyday life today, therefore it is especially important now to understand and comprehend general guidelines of possible development of Life and Education for tomorrow (Scharmer, 2016; Sorder, 2019).

Modern problems are complex – they are characterized by high-level internal as well as external diversity and high speed of corresponding changes. Today we need to start with the change of traditional arrangement of our World of Thoughts and getting general orientation within our modern Life activities. Concentration on basic key words (diverse, fast, stochastic/probabilistic, particular and general, quantitative and qualitative, private life and social life etc. changes) can help us to arrange our modern world outlook. We are especially interested in creation of things with new properties to satisfy our life new practical needs. Developing smart technologies, above all we need to develop also smart people by means of their smart education.

One of the top concepts is formulated as "sustainable development of humans' life". It means study and development of predictable long-time changes. Other general guideline is fundamental causality concept – "cause of everything is interconnection of everything". Finally, all changes should be studied, projected and realized using systems approach (Broks, 2014; 2016). When developing solutions of new particular problems, it is worth to follow fundamental reliable general concepts.

What EDUCATION for what LIFE - such is the question!

		DEVELOPMENT	CONSUMPTION
SCIENTIFIC education	Mind (concepts)	Fundamental and applied research	Technical maintenance
ARTISTIC education	Feelings (images)	Inspiration	Social life
PRAGMATIC education	Will (needs)	Practical creation	Use of science and art achievements

Figure 9. What EDUCATION for what LIFE – such is the question.

Education as life experience for life is coming on the top of Life activities today (Figure 9).

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HOW TO MAKE LEARNING IN STEM MEANIGFUL FOR THE MILLENNIUM GENERATION

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Abstract

The education of today more and more encounters the teaching and learning problems of young adults therefore it is topical to find out how to make the teaching/learning of the Millennium generation meaningful. This issue is especially important in STEM education. The survey involved Grade 10-12 students of Latvia, in total 256 students. Spearman's correlations and Kruskal-Wallis test were used in the data analysis. The obtained results showed that students- millennials as regards the learning of STEM subjects can be described as real-life oriented, digitally educated who want to participate actively in the teaching/learning process and who want to receive the feedback.
Keywords: *meaningful learning, Millennium generation, teaching and learning principles, STEM learning*.

Introduction

Qualitative education is needed for the person not only to adapt to the rapidly changing technologies but also to self-realize oneself successfully in the changing world of the future. The formation of the knowledge system, the acquisition of strategies, methods and methodologies, the skill to adapt to the new ways of acting and the communication means corresponding to them and not the scope of knowledge, its acquisition and transfer come to the foreground in the structure of the educational aims.

STEM education is important in the general education system (Hunter, 2013). STEM teaching and learning is complicated because the learner has to acquire higher order cognitive skills that are needed to comprehend the content of the subject and the application of knowledge in order to find solutions in real situations. World Economic Forum (2016) admits that students of the 21st century have to acquire not only academic knowledge but also collaboration, communication, and problem solving, which are some of the skills developed through social and emotional learning.

According to the generational theory also known as the Fourth Turning theory (Howe & Strauss, 1997), all students of today belong to the Millennium and Z generations (Generation Y, 1984-1999 year of birth) and Z generation (Generation Next or Z, 2000 - …… year of birth) or, summarizing the views expressed by Howell and co-authors (2009), it can be considered that the target group of the present study is generation Y, known as the Millennial generation, referred also to individuals born between 1982 and 2005. Sometimes they are labelled as "Digital natives" and "Digital from birth" (Tapscott, 2009). Actually, the topical question is whether the school should ignore the peculiarities of the learning of the new generation considering that a particular group needs special authorities (Kirschner & De Bruyckere, 2017), or still look for new possibilities to develop the educational approach, which will be radically different from that of previous generations.

The common dominates in the opinions expressed by the researchers - students who were born in the age of digital media are fundamentally different from previous generations of students. These students have been labelled digital natives and have been ascribed the ability to cognitively process multiple sources of information simultaneously (i.e., they can multitask) (Kirschner & De Bruyckere, 2017). This means that modern students are characterized by "clip thinking" and active participation in the multimedia environment; however, at the same time they are characterized by weakening of analytical skills, inability to concentrate, computer dependency and worsening of social communication skills (Howell, Joad, Callahan, Servis, & Bonham, 2009; Jain, 2015).

Thus, rapid spread of scientific cognition inevitably raises new challenges for natural education (Lamanauskas, 2013), i.e., the necessity to find new approaches in the education process, to find an individual trajectory for each student - the route in education that would correspond to his/her peculiarities and needs (Sharples et al., 2016) so that STEM acquisition at school would become meaningful. Meaningful learning means that the student has to link the new information with the previous knowledge during an active teaching/learning process restructuring and reorganizing the obtained information so that new knowledge could be applied in different situations and contexts (Trifone, 2006). When organizing the teaching/learning process, the teacher should adjust to the needs of the Millennium generation, and in the acquisition of STEM focus on the development of higher order thinking, using technology in the context of learning, e-communication and collaboration.

As the millennials do not like the feeling of "being taught" and would make an effort to learn when they are the masters of the situation then it would be advisable to ensure the teaching/learning environment in order to stimulate self-directed learning, and the teacher should focus on an individualized teaching/learning process. Millennials prefer environments which are more inclusive, therefore they should be provided with strong peer to peer learning and group work. Millennials are focused on the acquisition of practical skills necessary for the concrete situation and for life therefore the acquisition of STEM should include practical activities related to the solution of real – life situations (Howell, Joad, Callahan, Servis, & Bonham, 2009; Jain, 2015).

The aim of the present research was to find out how to make the acquisition of STEM meaningful for the Millennium generation in the teaching/learning process at school.

The research question: how do students of the Millennium generation perceive STEM learning at school?

Research Methodology

A pilot study by using the questionnaire developed in ERASMUS+ project 'International Diploma for Teacher in Education (eSTEM)' was conducted in December 2017 with the aim to clarify the secondary school students' views on STEM education. The questionnaire was structured in two parts: general and conceptual. The general part characterized student's gender, type of school, and grade, but the conceptual part of the survey identified such issues as curriculum, teaching methods and strategies, students' learning, teaching aids, assessment, school environment and support.

The research involved 256 students from secondary schools and gymnasia of Latvia learning in Grade 10th (n=96), 11th (n=112) and 12th (n=48), of whom 161 were female and 95 male students. The data have been obtained by using of closed-open items using 5-point Likert scale in the online platform of *QuestionPro*. The Cronbach's alpha test was used for internal consistency of the questionnaire. One sample Kolmogorov-Smirnov test helped to test that data follows a normal distribution. As the empirical distribution did not follow to the normal then Spearman's correlation analysis was used to determine the relations of the variables. The Kruskal-Wallis H test was used to determine if there were statistically significant differences between several groups of respondents.

Research Results

The Cronbach's alpha (α = .94) value testifies to the good consistency of the questionnaire items. On the one hand, it testifies about the measuring of the feature with the help of mutually replaceable but content-wise similar questions and, on the other hand, about students' honest attitude to the survey. Figure 1 presents the statistically most significant Spearman correlations (p = 0.01) that comprise three blocks of items. There is a very strong correlation (r = .80) between items about receiving the feedback from classmates and the possibility of self-assessment.

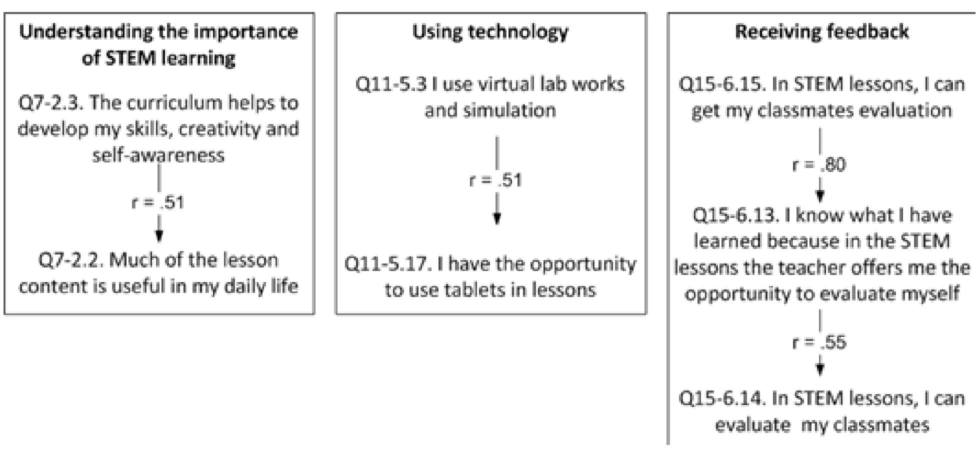

Figure 1. The most characteristic correlations about STEM learning.

The survey proves that, in general, students understand well the role of STEM subjects; they see the connection between the knowledge and skills acquired at school with the daily life and express the willingness to participate actively in the teaching/ learning process at school. However, students perceive differently the STEM learning. The opinions differ considerably on whether learning STEM subjects is difficult. Approximately a quarter of respondents consider that learning is difficult (*agree* and *strongly agree*) (Table 1).

Table 1. Students views of STEM subjects learning difficulties

Item	*M*	*SD*	*Median*	Distribution of answers (%)				
				Strongly disagree (1)	Disa-gree (2)	Neither agree or disa-gree (3)	Agree (4)	Strongly agree (5)
Q7-2.4. It is difficult for me to learn STEM	2.87	1.00	3	6.6	31.3	36.3	19.9	5.9

When acquiring STEM subjects, it is important to ensure that they do not seem too difficult for students. Depending on the answers to Q7-2.4 according to Likert's scale students were divided into 5 groups. Applying the Kruskal-Wallis H test, it was identified that there were statistically significant differences to several questions related to the STEM learning among these groups (Table 2). The results showed that learning difficulties are connected with the lack of motivation that result from insufficient appreciation of the teacher's work and failing to see the meaning of learning STEM subjects.

Table 2. Some important differences among students' groups.

Item	*M*	*SD*	*Median*	Chi-Square (χ^2)	*df*	*p*
Q20-3.12. The teacher helps me to develop thinking	3.53	.84	4.00	26.30	4	<.001
Q20-3.13. The teacher encourages me to new ideas	3.26	.90	3.00	18.23	4	.001
Q11-4.5. STEM topics that are acquired at school are not useful for daily life	2.73	1.02	3.00	13.67	4	.008
Q11-4.14. STEM learning attracts my interest and I feel good	3.23	1.00	3.00	17.37	4	.002
Q11-4.15. I am able to use well modern tech-nologies in the learning process	3.77	.96	4.00	12.38	4	.015
Q13-5.12. I participate in the on-line courses MOOCs	1.73	.93	1.00	19.45	4	.001

a. Kruskal-Wallis test
b. Grouping Variable: Q7 - 2.4. It is difficult for me to learn STEM

Although the majority of students assessed highly their skill of using modern technologies, the low mean value of item Q13-5.12 still shows that schools actually do not use the possibility of learning through massive open online courses (MOOCs) that could serve as an excellent resource for supplementing student's knowledge and diversifying the learning methods.

Conclusions and Implications

Certain regularities are observed that characterize students of the Millennium generation and thus highlight some essential indications how to improve a meaningful, real - life connected STEM teaching/learning process.

The student wants to be an active learner, he/she wants to receive an immediate feedback for his/her action both from the teacher and the classmate as well as be the evaluator him/herself – to assess oneself and to evaluate the classmate. The use of technologies is also significant for the student because he/she is certain about his/her digital literacy.

The dramatic differences between the opinions and awareness of different students testify about the complex character of STEM learning, which, in its turn, requires individualized approach in the development of diverse skills.

The study is being continued. It is envisaged to find out in more detail the common and the different features among students who have a different attitude to STEM learning. Teachers are being surveyed along with the students, thus, it will be possible to compare the opinions of two target groups on similar questions. The results of the study could be useful for a better understanding of STEM teaching/learning strategies in Latvia.

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MEASURING KNOWLEDGE GROWTH FOR INDIVIDUAL BACHELOR STUDENTS AT SCIENCE COURSES OF UNIVERSITY OF LATVIA

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Abstract

The purpose of this study is to measure the development of students' conceptual understanding of basic physics concepts at introductory physics courses at the University of Latvia. The authors of the research have translated, tested and verified the Force Concept Inventory and other Concept Inventories in the context of Latvian education system. The results demonstrated a low improvement of physics understanding using present lecturing approach, which suggests the need for an active learning environment and student-centred learning approach in physics courses at University of Latvia. Due to the very small number of physics graduates from physics faculties in Latvia and especially small number of physics teachers, it becomes increasingly important that these students acquire good conceptual understanding of physics.
Keywords: *STEM education, conceptual understanding, evidence-based approaches*.

Introduction

Latvia is in a transition state with respect to the implementations of STEM education research into the study programs. On the one hand, a new, uniform education concept is being developed in the country, from pre-primary to high school. The need for reform has been demonstrated by the results of the OECD (2019, 07 May) as well as the demand of today's labour market. On the other hand, it is unclear whether university science faculties are ready for such a reform. There is scepticism among lecturers towards active-learning methods that are shown by physics education research to be more efficient than lecturing (Lasry, Watkins, Mazur, & Ibrahim, 2013). Lecturers, for a variety of reasons, avoid measuring the growth of knowledge and the growth of understanding of their students, at the same time expressing doubts about students' understanding of the basic laws of physics. However, these concerns are based only on the subjective views of lecturers, not on any measurements. The authors of this study are not aware of the measurements of student conceptual knowledge development in physics courses at Latvian universities using Concept Inventories widely used by physics education research worldwide. The Force Concept Inventory and other Concept Inventories were translated and tested, in order to measure the student's understanding of basic concepts of physics and the effectiveness of learning process during the bachelor physics courses. The results obtained are in accord with the results obtained by other physics education research groups.

Research Methodology

General Background

To compare the growth of the conceptual knowledge of students in Latvia to students elsewhere in the world, the Force Concept Inventory (*FCI*) was used. FCI was developed and first applied by Hestenes, Wells and Swackhamer (1992, March). Nowadays, the *FCI* has been administered to more than a hundred thousand students at many universities worldwide and as the research by Von Korff et al. (2016) suggests, interactive engagement teaching techniques are significantly more likely to produce high student learning gains than traditional lecturing approach.

Participants

Students of physics bachelor's course in the autumn semester of 2018 of the University of Latvia were involved in the research. 52 students participated in the study, however, only 29 students did all the phases of the test. The results presented here are for these students participating in all phases of the test.

All participants had a high-school general physics course education before being accepted to the university and all have passed the centralized exam at the end of high school. Participants were 18–20 years old, 48% were female and 52% male.

Research Design

The *FCI* test was translated and tested on faculty members for error correction. In the first physics lesson the *FCI* pre-tests were completed by all students. The translated test preserves the original *FCI* multiple-choice test format. Test conditions and time limit was set and strictly observed (Hestenes et al., 1992). Lecturers did not see the questions of the tests in order to avoid preparing the students to post-test. However, the lecturers were able to learn which students have a better or weaker knowledge of physics. Information on how students answer questions about the specific topics of the mechanics was also available to lecturers. Therefore, the pre-test was a starting diagnostic of student initial knowledge and understanding. At the end of the course, students answered the post-test questions, which were the same as pre-test questions.

The effectiveness of teaching is characterized by gain, , that is calculated as

$$< g > = \frac{<Post> - <Pre>}{100 - <Pre>},$$

where *<Post>* is group average post-test result and *<Pre>* is group average pre-test result. The gain can be understood as relative increase of the student knowledge between pre-test and post-test with respect to the maximal possible increase. In other words, the gain can be interpreted as potential growth that has been achieved relatively to the maximum possible outcome. The average gain <*g* > between 0 to 34% (Hestenes et al., 1992; Lasry et al., 2013) indicates a typical for traditional teaching approach and low student engagement.

Hestenes and Halloun, 1995 showed the level of the understanding of the mechanics is characterized by the test score. High level of understanding of the mechanics corresponds to the result in the test of 80—100% range, 60—80% range is shown by students with an understanding of the basic concepts of Newton mechanics. A third of the group with the score below 60% has a very low understanding of the mechanics.

Research Results

The calculated normalized gain of the group:

$$< g > = \frac{<Post> - <Pre>}{100 - <Pre>} = \frac{65-54}{100-54} = \frac{11\%}{46\%} = 23\% \text{ (\textit{Standard deviation 11\%})}$$

The group's average gain *<g>* of students at University of Latvia belongs to the group of results that demonstrate low learning effectiveness, see Figure 1. As demonstrated by other research groups (Hestenes et al., 1992; Lasry et al., 2013), our students demonstrate the gain typical to the traditional learning approach, which results in low student knowledge growth during the course.

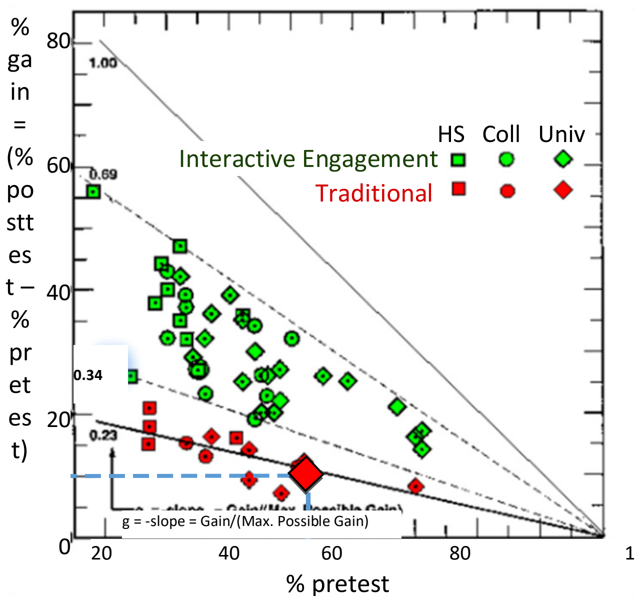

Figure 1. Test results at the University of Latvia, large red diamond, compared to the data of the research of Hestenes et. all (1992). Adapted from Hestenes et. all (1992).

To interpret the individual growth for each student, the level of the understanding of the mechanics was analysed. (Hestenes & Halloun, 1995). Only a small part of students had demonstrated high understanding of the mechanics, see Figure 2. Other students with low understanding of basic concepts of physics are not prepared to acquiring more complicated physics concepts in their further studies.

The correlation between the following parameters: enrolment exam scores at the university and whether the student continued studies in the 2-nd semester was additionally explored. No correlation between these parameters was found.

The research also yielded some unexpected results. For most of students' improvement was as expected – about 20—40 %. Surprisingly several students have shown a negative gain.

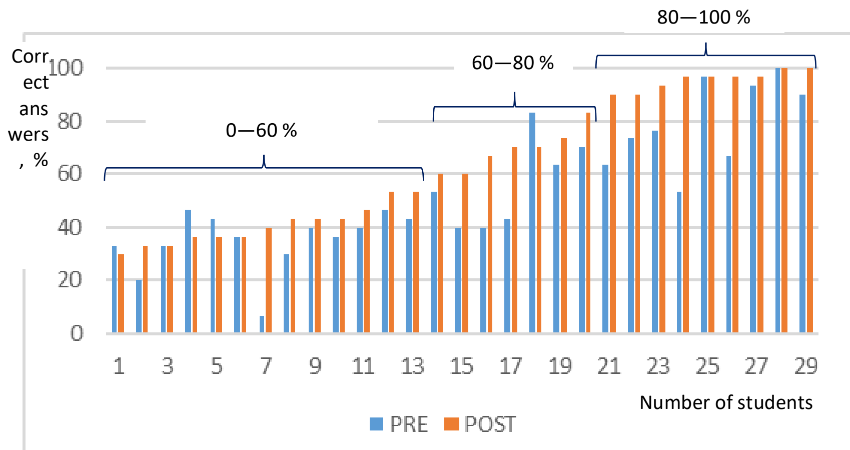

Figure 2. Individual results of students' pre and post test – only third of students have understanding of basic physics laws at the end of the course.
Data of University of Latvia, physics bachelors group, 2018 Full semester.

The research was repeated and the results were compared with a measurement in another university of Latvia – Ventspils University, a general physics course for students of the Bachelor of Electrical Engineering and Radio Electronics for the autumn semester of 2018. The result showed similar 24% gain. In addition to the Force Concept inventory test, it was also performed the gain measurement in the electrodynamics course. A measurement is currently being made for the course of the thermodynamics in the spring semester 2019.

Analysis of Results

Comparing the gain in University of Latvia to the results obtained in recent years elsewhere in the world, it can be seen that students in Latvia show a low result. For example, Georgia States Universities, US, recent study using *FCI* test included more than 5,000 students. The results show the average gain that range from 47.4% up to 71.3%. (Caballero, Greco, Murray, Bujak, & Marr, 2012). In turn in the research at the University of Toronto first year Physics course (Lasry, Watkins, Mazur, & Ibrahim, 2013) gives gains values of 45.02% for the fall session and 34.03% for the summer session. The research conducted in the Physics and Astronomy New Faculty Workshop (Lee, Manju, Dancy, Henderson, & Christensen, 2018) the average gain between 40-60% was measured. The University of Latvia's result is below these results obtained in recent years.

Conclusions and Implications

The students from the University of Latvia physics course showed the results that present challenges for the traditional lecturers. The results of the present research demonstrated the need for student engagement in the process of learning and student-centred methods (in physics and supposedly in other natural sciences) if better conceptual knowledge of graduates is expected. Particularly, taking into account the small number of physics graduates continuing to work as teachers in schools, it will be impossible to replace the retiring physics teachers by new teachers with good conceptual understanding of physics.

The *FCI* test results in the University of Latvia agree to the worldwide results described in scientific literature by several authors at different universities for the time period 1995—2014 using *FCI* and showing that traditional learning methods lead to 22% gain while interactive approach provides gain of 39% on average (Von Korff et. all., 2016). The approach presented here will be used to find the learning approach at the University of Latvia that leads to higher conceptual understanding of physics by students. The authors of this research are not aware of similar studies carried out in Latvia or elsewhere in the Baltic States. The authors call for the wider use of pre-tests and post-tests to measure the quality of physics education at university study courses.

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LESSON STUDY AS A PROCESS FOR DEVELOPING THE PEDAGOGICAL CONTENT KNOWLEDGE OF PRE-SERVICE PHYSICS AND CHEMISTRY TEACHERS

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Abstract

This research aimed to understand what physics and chemistry pre-service teachers learn within pedagogical content knowledge in a lesson study with the topic speed of sound, 8th grade. Participants were three pre-service teachers. This was a qualitative and interpretative study. Data were collected from participant observation, individual interviews and individual written reflections. Results showed that the participants developed their pedagogical content knowledge, when they identified the students' prior knowledge and when they discussed strategies to help students overcome their difficulties.
Keywords: *initial teacher education, lesson study, pre-service teachers, professional development, science education.*

Introduction

Pre-service teachers need to know how to support students in learning science. To achieve this goal is the key since what is taught and how it is taught impacts on what students learn (Darling-Hammond, 2000). Therefore, in initial teacher education, pre-service teachers should develop pedagogical content knowledge (PCK), that is, the knowledge they need to make scientific concepts understandable to students (Shulman, 1986). The nature of this knowledge has been the object of attention for several authors. In this research our vision of PCK is in line with the results of PCK Summit (Gess-Newsome, 2015), i.e., PCK is the teaching knowledge and skills required to plan and teach a lesson about a topic, to a specific group of students, and how these are put into practice in order to improve students results. The education literature acknowledges that PCK is dynamic and develops as a consequence of teacher involvement in lesson planning, lesson delivery and subsequent reflection on the teaching methods used and what the students learned (Nilsson, 2008). Nilsson and Loughran (2012) have justified that this knowledge is difficult for pre-service teachers since they still miss the ability to see beyond what they observe. Another inhibitor to the development of the PCK of pre-service teachers is that they tend to value a teacher-centred approach, preferring closed tasks to having students work collaboratively (Uşak, 2009). Nevertheless, there is an evidence that an organised and well-structured combination of the teacher education course syllabus alongside school activities will translate into significant professional development (NRC, 1996; Zeichner, 2010). However, this combination is complex and it is not always feasible. As such, this is one of the reasons why some teacher education programmes are not very successful (Zeichner, 2010). Consequently, pre-service teachers do not develop in-depth PCK (Feiman-Nemser & Parker, 1990) and they are not able to use what they know to help their students learn (Gess-Newsome & Lederman, 1993). Accordingly, teacher education programmes need to promote effective collaboration between the university and the school and assist pre-service teachers to understand what is behind the difficulties experienced by the students, how these impact on lesson planning and delivery and what these teachers can do to help students learn. In lesson study (*jugyo kenkyuu*, in Japanese), educators, teachers and researchers support pre-service teachers to solve problems related to student learning and to reflect on the impact of the teaching decisions put into practice in the classroom. Research results on the use of lesson study as a teacher education process for pre-service teachers have been promising (e.g., Munthe, Bjuland, & Helgevold, 2016; Zhou, Xu, & Martinovic, 2016). However, there is scarce research regarding their potential in the development of PCK, even scarcer in initial teacher education. This research aims to understand what physics and chemistry pre-service teachers learn within PCK when they participate in a lesson study in the teaching of the speed of sound, 8th grade, in a lesson lectured by a cooperating teacher.

Research Methodology

This research was qualitative and interpretive based on naturalistic observation (Erickson, 1986) and was carried out during a curricular unit of the master's degree in physics and chemistry teaching, with all students attending the master degree - first year, 2nd semester (Caroline, Philip and Sarah). This lesson study had two cycles of twelve sessions. The planning phase took place over eight sessions, followed by the research lesson (session 9) and the post lesson reflection (session 10); the second cycle included the second research lesson (session 11) and the respective post lesson reflection (session 12). In addition to the three pre-service teachers, the project leader of lesson studies (João Pedro) also participated in the sessions, the teacher of the curricular unit (Mónica), the cooperating teacher (Carla) and the researcher (Teresa). The two research lessons were taught by the cooperating teacher and the remaining participants in the lesson study were observers. Data were collected from the participant observation of all sessions using field notes and video recording (VR). Moreover, data were collected from individual interviews (I) conducted with pre-service teachers at the end of the lesson study, and from individual written reflections (IWR) by pre-service teachers carried out at the end of the lesson study.

Research Results

Pre-service teachers' learning progress regarding the teaching of the topic. During the planning sessions, there were discussions on how to help the students learn the speed of sound. Such discussions were a very productive learning opportunity for pre-service teachers to develop PCK. For instance, drawing on their reflections on the students' answers to the diagnostic task, the pre-service teachers were able to share what students already knew on distance variable: "As positive aspects were highlighted the following strategies used by the students to determine the distance travelled by the ball as some of the students multiplied 2 m × 6 units, and others added up" (Caroline, VR), and "many of them have an adequate reasoning. Almost everyone calculated the distance travelled by the ball." (Philip, VR). As acknowledged by the pre-service teachers, the students showed understanding about distance variable. Accordingly, Sarah commented that "if the students already know what the distance is, they can calculate the distance of sound propagation by themselves"(VR). When considering the distance variable as an anchor for students to understand the concept of the topic, teachers developed their PCK in teaching the topic.

Pre-service teachers' learning progress about students' difficulties. In the post-lesson reflection session, the analysis of the students' results evidenced learning difficulties. According to Caroline, "the students calculated the speed of the sound dividing the distance of sound propagation by time interval, but they didn't understand its meaning" (IWR). Sarah, also mentioned "To calculate the speed of sound was not difficult for the students. I think, the most difficult was to understand what means 340 m/s" (I). As such, the strategies that may help the students were discussed. One of these strategies was suggested by Philip, when he said that "after the students calculated the speed of sound, the cooperating teacher could start a collective discussion by asking the following questions in the classroom: In 1 s what is the distance covered by sound? And in 1,5 s? How long does it take the sound to travel 340 m? And twice? These reasonings are an opportunity to encourage students to explain the meaning of the speed of sound and recognize the constant value of the speed of sound in the air" (VR). Caroline agreed with Philip when, in the interview, she mentioned: "to discuss the meaning of the speed of sound in the classroom was a good strategy. Because when students explain their reasoning, is easier to help them, is much easier" (I). So, the teachers' strategies to help students overcome their difficulties, showed that they developed their PCK about students' difficulties. Indeed, student background knowledge and difficulties had impact on pre-service teachers' instructional decisions.

Conclusions

Pre-service teachers of physics and chemistry need to develop their PCK. So, it is important to stimulate PCK in initial teacher education. This is achievable, as shown in this lesson study. Over the course of twelve sessions, pre-service teachers learned how to devise a lesson plan on a topic, considering issues related to student learning, to analysing learning results, and to identifying problems and how to solve them. These findings show the potential of lesson study in the development of the PCK of these three pre-service teachers. More studies are necessary with a larger sample to generalise the potential of this teacher education model in initial teacher education. Moreover, in this study, pre-service teachers observed research lessons taught by an experienced teacher. However, since teaching is a very complex activity, we consider important to carry out other lesson studies in initial teacher education with pre-service teachers teaching a lesson.

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EXAMINING THE PSYCHOMETRIC PROPERTIES OF A MALAYSIAN RELEVANCE OF SCIENCE EDUCATION (MROSE) QUESTIONNAIRE USING PARTIAL LEAST SQUARES STRUCTURAL EQUATION MODELING (PLS-SEM)

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Abstract

This research is aimed to validate an instrument, the Malaysian version of ROSE or MROSE to gauge Malaysian secondary students' interests, attitudes, values, and priorities in S&T-related issues. Partial Least Squares-Structural Equation Modeling approach was used to evaluate the validity and reliability of the instrument. The internal consistency reliability (composite reliability and Cronbach's Alpha coefficient), convergent validity (Average Variance Extracted), and discriminant validity (cross loadings, Fornell-Larcker criterion, and Heterotrait-Monotrait ratio) for each individual item of the instrument were being assessed.
Keywords: *affective factor, PLS-SEM, science and technology, relevance of science education (ROSE).*

Background

The Relevance of Science Education (ROSE) is a cooperative research project with wide international participation, addressing mainly the affective dimensions of how young learners relate to Science and Technology (S&T). The purpose of ROSE is to gather and analyze information from the learners about several the factors that have a bearing on their attitudes and motivation to learn S&T. These include a variety of S&T-related out-of-school experiences, interests in learning various S&T topics in different contexts, prior experiences with and views on school science, views and attitudes to science as well as scientists in society, future hopes, priorities and aspirations as well as young people's feeling of empowerment with regards to environmental challenges, etc.

Problem Statement

Through international deliberations, workshops and pilot studies among many research partners, ROSE has developed an instrument that aims to map out attitudinal or affective perspectives on S&T in education and in society as seen by 15- year old learners. The ROSE advisory group comprises key international science educators from all continents. They have tried to make an instrument that can be used in widely different cultures. The aim is to stimulate research cooperation and networking across cultural barriers as well as to promote an informed discussion on how to make science education more relevant, also meaningful for learners in ways that respect gender differences and cultural diversity. The ROSE international science educators also hope to shed light on how they can stimulate the students' interest in choosing S&T-related studies and careers as well as to stimulate their life-long interest in and respect for S&T as part of their common culture. To ensure the ROSE instrument is free from gender and cultural bias in Malaysian context, it is extremely crucial to validate a Malaysian version of Relevance of Science Education (MROSE) Questionnaire as a valid and reliable measure of Malaysian secondary students' interests, attitudes, values, and priorities in S&T-related issues.

Research Aim

This research embarks on a research objective to validate a Malaysian Relevance of Science Education (MROSE) Questionnaire to gauge Malaysian secondary students' interests, attitudes, values, and priorities in issues related to science and technology.

Research Methodology

Population

The Relevance of Science Education (ROSE) target population is the cohort of all 15-year-old students, or the grade level where most 15-year old students are likely to go. In Malaysia, this corresponds to the last year attendance of lower secondary school (Form 3 or Grade 8). However, this cohort of students is not accessible to researchers as they will be sitting for a lower secondary examination, or in Malay language *Pentaksiran Tingkatan Tiga* (PT3), and the Ministry of Education will deny researcher permission to conduct research on them. For this reason, the Malaysian ROSE target population has to be altered to the cohort of students of 16- year old who have just entered Form 4 (Grade 9) and the survey was conducted at the early part of the school year. As ROSE samples school classes and not individual students, the Malaysian accessible population is more precisely defined as the classes at the early stage of Form 4 where most 16-year old students are likely to go.

Sample and Participation

A list of all secondary schools in Sabah and their relevant statistics for 2018 was obtained from the Sabah State Education Department. The samples of this study were drawn from the list using a stratified sampling routine. The first sampling unit is the school. Once the schools were selected, the Form 4 classes in these schools were made the targets of a second random sampling routine. The science teachers who have been appointed as the research assistants in the selected secondary school have carried out the random sampling routine. Once the classes were chosen, the students in these classes formed the samples of this study.

Due of budget limitation, the research team had adopted a stratified sampling strategy based on geographical region in Sabah, i.e. West Coast Division, Interior Division, Kudat Division, Sandakan Division, and Tawau Division. Using a computer random generator, one school was drawn from each division of Sabah. The resulting sample of 5 schools is expected to possess the essential state characteristics.

Official letters were sent to the sampled schools inviting them to participate in the revised ROSE survey. A description of the ROSE project together with copies of the permission letter from the Educational Planning and Research Division, Ministry of Education and the Sabah State Education Department were attached. The school principals were asked to enclose statistics on the number of Form 4 classes by stream (track) and the number of students in each class for further sampling purpose. For practical purposes, the sampling of the classes was performed by the research assistant in the selected school. Specific instruction was given to the research assistants to randomly select two science classes and two non-science classes that were involved in this study.

Instrument

Student Background Questionnaire (cover sheet)

The cover sheet of the MROSE questionnaire contains five classification questions: age, gender, region, school location, track (science or non-science).

A. "What I Want to Learn About" (48 items)

This dimension of questions will give empirical evidence on what topics various groups of students are interested in learning about. This insight can inform our discussions on how S&T curricula can be constructed in order to meet the interests of different groups of learners. It should be emphasized that the prime concern behind this question is that science lessons should engage the students. Asking the students how interested they are in various topics is one approach for getting in touch with science lessons' potential for engagement. However, engagement does not refer simply to enthusiasm, entertainment and fun. It is also important to trigger concern, provoke creative thinking and stimulate individual growth.

B. "My Future Job" (26 items)

This question provides information about the future priorities and motivations of the students. This is in itself interesting information and allows for comparisons across cultures and between various groups of students.

C. "What I Want to Learn About" (18 items)

Under this heading, the following instructions are given: How interested are you in learning about the following? (Give your answer with a tick on each line. If you do not understand, leave the line blank).

D. “Me and the Environmental Challenges” (18 items)

Empowering students to deal responsibly with the environmental issue should be an important goal of education. As science educators we need to develop knowledge and awareness of what challenges we are facing in our efforts to make students equipped to meet the environmental problems. Research in science education have taught us a lot about students’ conceptual understandings (and ‘misconceptions’ or ‘alternative conceptions’) of science contents, but less about their attitudes, priorities, and decision-making regarding environmental matters. This part of the questionnaire will deepen our understanding of how youth relate to some environmental issues, and the results against perspectives from sociology and youth research will be interpreted.

E. “What I Want to Learn About” (42 items)

Under this heading, the following instructions are given: *How interested are you in learning about the following? (Give your answer with a tick on each line. If you do not understand, leave the line blank).*

F. “My Science Classes” (16 items)

Under this heading, the following instructions are given: *To what extent do you agree with the following statements about the science that you may have had at school? (Give your answer with a tick on each line. If you do not understand, leave the line blank)*

G. “My Opinions about Science and Technology” (16 items)

Under this heading, the following instructions are given: *To what extent do you agree with the following statements? (Give your answer with a tick on each line. If you do not understand, leave the line blank)*

H. “My Out-of-School Experiences” (61 items)

Under this heading, the following instructions are given: *How often have you done this outside school? (Give your answer with a tick on each line. If you do not understand, leave the line blank)*

Data Analysis Procedures

Partial Least Squares-Structural Equation Modeling (PLS-SEM) approach was used to evaluate the validity and reliability of the MROSE questionnaire. Before running PLS-SEM analysis, the data collected were screened to ensure error free from missing value, suspicious response patterns, and outliers. Results from the statistical analysis were being reviewed and evaluated in terms of the relation among items in the measurement model. To ascertain the validity and reliability of the MROSE questionnaire, the internal consistency reliability, convergent validity, and discriminant validity of each individual item were being assessed. In particular, internal consistency reliability for each subscale was determined through the composite reliability (CR) and Cronbach’s Alpha (CA) coefficient. The Average Variance Extracted (AVE) was evaluated to assess the convergent validity of the instrument. Cross-loadings, Fornell-Larcker criterion, and Heterotrait-Monotrait ratio (HTMT) were also assessed to evaluate the discriminant validity for each item in the MROSE instrument.

Research Results

The ultimate goal of this study is to examine the validity and reliability of a Malaysian Relevance of Science Education (MROSE) questionnaire by using PLS-SEM approach. Reflective and formative measurement models have been developed and evaluated to assess the validity and reliability of the MROSE questionnaire using PLS-SEM approach. Figure 1 depicted the measurement models of MROSE questionnaire after item deletion. The measurement models consist of five latent constructs which are ‘Me and the Environmental Challenges (MEC)’, ‘My Out-of-school Experiences (OOSE)’, ‘My Science Classes’ (MSC). ‘My Opinion about Science and Technology (MOST)’, and ‘My Future Job (MFJ)’.

The Assessment of Reflective Measurement Models

In assessing the reflective measurement models of the MROSE questionnaire, the internal consistency reliability and the discriminant validity of the measurement models are evaluated. According to Hair, Hult, Ringle, and Sarstedt (2017), the threshold value of the composite reliability (CR) ranges from .70 to .95 for an exploratory research, whereas the threshold value for Average Variance Extracted (AVE) is above .50.

Table 2 showed the Cronbach’s alpha, CR and AVE values for all the three reflectively measured latent constructs (i.e., MEC, MOST, and MSC) before item deletion. The Cronbach’s alpha for MEC, MOST, and MSC before item deletion are .540, .825, and .915, respectively. The CR values for MEC, MOST, and MSC are reported as .465, .866, and .923, respectively. All the three constructs reported AVE values less than .50, (i.e., .145, .366, and .443, respectively). Hence, the AVE values for all the three reflectively measured constructs did not meet the minimum threshold value of .50 as recommended by Hair et al. (2017). Therefore, all items with outer loadings range from .40 to .70 have been considered for item deletion, whereas items with outer loadings less than .40 have been eliminated from the measurement models.

Table 3 presents the deleted items based on the item outer loading assessment of the reflective measurement models. For the MSC construct, four items (F1, F3, F14, and F16) have been deleted from the measurement model which have led to the improvement of the outer loadings for the remaining items and also the AVE for each construct. As for the MOST construct, out of 16 items, seven items (G6, G7, G8, G9, G10, G12, G14) have been deleted. Out of 18 items in measuring the MEC construct, a total of 15 items (D1, D2, D3, D4, D5, D6, D8, D9, D11, D13, D14, D15, D16, D17, and D18) have been deleted due to low outer loadings.

After all items which have not met the minimum requirement of outer loadings as recommended in PLS-SEM (Hair et al., 2017), the validity and reliability of the reflectively measured constructs were reexamined and presented in Table 4. Based on the results shown in Table 4, the Cronbach’s alpha, CR, and AVE for all the three reflectively measured constructs have shown high reliability. The Cronbach’s alpha for MEC, MOST, and MSC is reported as .669, .873, and .916, respectively. The CR for MEC, MOST, and

MSC is reported as .802, .899, and .925, respectively. The AVE values for all the three reflectively measured constructs meet the minimum threshold value of .50.

On the other hand, the measurement models of the MROSE questionnaire have been assessed in terms of its discriminant validity through the heterotrait-monotrait ratio (HTMT). Based on the results shown in Table 5, the HTMT values for all the reflectively measured latent constructs are less than the threshold value of .85 which indicates that the constructs have high discriminant validity after item deletion.

The Assessment of Formative Measurement Models

As for the assessment of formative measurement models of the MROSE questionnaire, the collinearity issue has been checked via the variance inflation factor (VIF) values. Following this, the assessment of significance and relevance of the formative indicators were performed by means of bootstrapping procedure. According to Hair et al. (2017), formative indicators with VIF values exceed the minimum threshold of 5.0 need to be deleted. Appendix A presents the VIF values for all the items measuring MFJ and OOSE constructs after item deletion is made. It is clearly shown that all the items measuring MFJ and OOSE possessed VIF values less than 5.0. This indicates that both formatively measured constructs have no collinearity issue. Table 6 shows the assessment results for collinearity issue via VIF. All items measuring MFJ remained however eleven items (H11, H15, H16, H21, H34, H36, H46, H49, H56, H57, and H59) measuring OOSE have been deleted due to the VIF values exceeded the minimum threshold value of 5.0 (Hair et al., 2017).

Following the assessment of collinearity issue is the evaluation of the significance and relevance of the formative indicators by means of bootstrapping procedure. The bootstrapping results (Appendix B) showed the *p* values and the outer weight (OW) of all the formatively measured items. According to Hair et al. (2017), formative indicator which is non-significant ($p > .05$) with low outer weight below .10 must be deleted for further analysis. A total of 15 items measuring MFJ construct and 43 items measuring OOSE construct have been deleted from its respective formation measurement model as these items were not significant and with outer weights less than .01 (Table 7).

Conclusions

The assessment of reflective and formative measurement models in the MROSE questionnaire has shown that MROSE questionnaire is a valid and reliable instrument to measure Malaysian secondary students' interests, attitudes, values, and priorities in issues related to science and technology after item deletion is made. The remaining items in the reflective measurement models of the MROSE questionnaire have met the minimum threshold values as required by outer loading, Cronbach's alpha, composite reliability, average variance extracted, and heterotrait-monotrait ratio. On the other hand, the remaining items in the formative measurement models of the MROSE questionnaire have met the minimum threshold values of variance inflation factor and the significance and relevance assessment.

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ANALYSIS OF SOME SELECTED FORCE CONCEPT INVENTORY TASKS USING EYE-TRACKING AND CORRELATION WITH SCIENTIFIC REASONING SKILLS

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Abstract

The aim of the research was the analysis of the problem dealing with solving of six Force concept inventory tasks by first-year university students using obtained eye-tracking data. Some characteristics like attention maps and sequences of fixations provide a deeper insight into the students' approaches to the tasks verifying their conceptual understanding to Newtonian mechanics. It can be confirmed the correctly answering students found the correct solutions more straightforwardly making their decision between fewer options. This is also supported by the analysis of fixation numbers and fixation times. The results show differences in the way novices and experts process questions and enable to identify some persistent misconceptions.
Keywords: *eye-tracking, introductory physics course, scientific reasoning, solving tasks*.

Introduction

FCI (Force Concept Inventory) is probably the most commonly used diagnostic test to assess a student's knowledge of Newtonian mechanics (Hestenes, Wells & Swackhamer, 1992) and there are a number of studies on analysing and revising FCI. However, it is difficult but on the other hand of great interest to investigate what strategy students are using while trying to solve FCI questions. Measurement of eye movements provides some information about the underlying cognitive processes and visual attention during problem-solving. In recent years, eye-tracking has been increasingly used to explore how high-school or university students solve the problems from various parts of physics – see e.g. (Han, Chen, Fu, Fritchman, & Bao, 2017; Kekule & Viiri, 2018; Ohno, Shimojo, & Iwata, 2016; Susac, Bubic, Planinic, Movre, & Palmovic, 2019; Viiri, Kekule, Isoniemi, & Hautala, 2017).

The aim of the research was to bring another small step further into understanding students' minds, and in the evaluation of the problem-solving processes at the level of an undergraduate introductory physics course.

In science, technology, engineering, and mathematics education there is also increased emphasis on teaching goals that include not only the learning of content knowledge but also the development of scientific reasoning skills. The Lawson classroom test of scientific reasoning (LCTSR) is a popular assessment instrument for scientific reasoning (Lawson, 1978) with some of its components – proportional thinking, probabilistic thinking, correlational thinking, hypothetical-deductive reasoning. The research questions of the research were:

- Is it possible to find a correlation between the conceptual understanding of Newtonian mechanics and general scientific reasoning skills;
- Is it possible to confirm the correlation presented between students' scientific reasoning measured by LCTSR and conceptual understanding of the force concept obtained (Sriyansyah & Saepuzaman, 2017), and the outcomes of the study by (Bao et al., 2009a; Bao et al., 2009b).

Research Methodology

The Lawson classroom test of scientific reasoning was completed by twenty-one perspective physics teachers programme students of the Faculty of Science, Palacky University Olomouc, in their first year of their university bachelor study at the beginning of the first semester and once more eight weeks later. From the FCI test 6 multiple choice tasks were taken; all those selected problems included important graphical information presented through a picture. The students solved the problems after completing the corresponding parts within an introductory course of classical mechanics (8 weeks of lectures and seminars instruction), the problems covered the kinematics, the first and the second Newton laws and the motion in the homogeneous gravitational field. Two of the tasks showed as rather difficult (with the item difficulty index values .29 and .19 respectively).

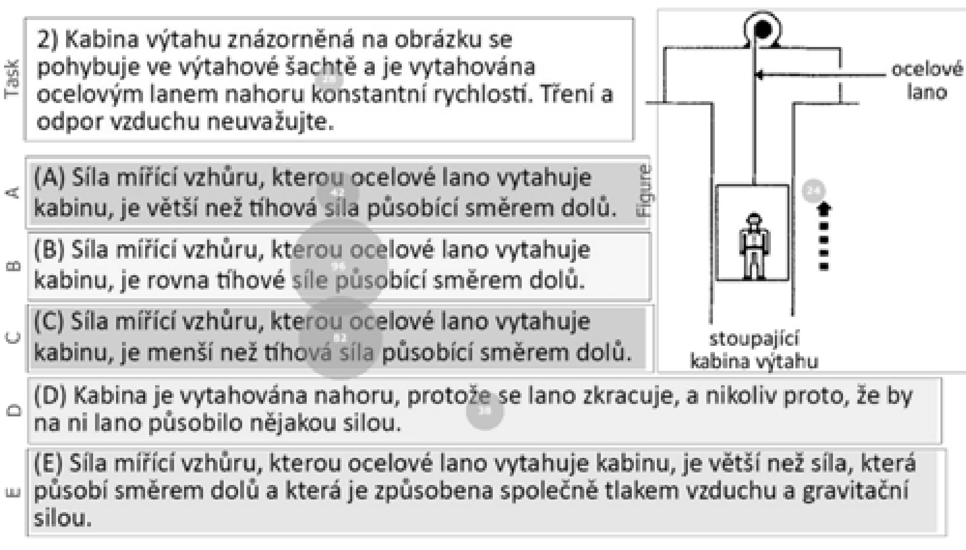

Figure 1. Example of areas of interest for the well-known FCI elevator task (translated into Czech). Though a large attention was devoted to the right answer (B), the wrong distractor (C) connected with a frequent misconception gets also quite a large spot.

For the measurement the Gazepoint GP3 eye tracker with the sampling rate 60 Hz and spatial resolution (RMS) 0.1 degree was used. The problems were displayed on a computer screen, placed in front of the participants, who were asked to read and solve each task silently, and say the answer aloud when they have solved the problem. There was a time limit of 15 min to complete all the 6 tasks. The data were then processed and analysed by Ogama program. Several areas of interest for each task (questions, multiple choice distractors and related pictures were defined. Attention maps for the areas of interest and sequences of fixations for each problem and all participants were compared (see e.g. Figure 1 showing count of fixations for each area for one student). Also, some eye-tracking measures were calculated including viewing times, numbers of fixations and average fixation durations.

Research Results

A statistically significant correlation between students' scientific reasoning measured by LCTSR and conceptual understanding of force concept has not been confirmed, the results in both our tests have Spearman's rank correlation coefficient 0.219. It was found out that for our students the rigorous learning of physics knowledge is not so strongly affected by their general scientific reasoning ability.

The eye-tracking data shows, that on average the students choosing the right answer come to their conclusion more smoothly and in a shorter time than those who are hesitating and take the wrong distractor in the end. This is confirmed by a moderate correlation between the test score and path velocity of their eye-tracking in pixels per second (Spearman's rank correlation coefficient .492).

Conclusions

The outcome of the eye-tracking analysis confirmed that more successful students tended to focus faster and spend more time on task-relevant details, sometimes they were able to proceed to the right answer straightforwardly after reading the main part of the question. Due to the test problem distractors, we were also able to identify persistent misconceptions connected with the first Newton law for uniform rectilinear motion and the composition of motions in a uniform gravitational field.

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VALIDATION OF METHOD FOR THE ASSESSMENT OF COGNITIVE COMPLEXITY OF CHEMICAL TECHNOLOGY PROBLEM TASKS

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Abstract

The aim of research was validation of a method for the assessment of cognitive complexity of chemical technology problem tasks. The method included an assessment of the difficulty of concepts and an assessment of their interactivity. As a research instrument for assessing performance, test of knowledge was used. Each task in the test was followed by a 5-point Likert scale for the evaluation of invested mental effort. The validity of this method was confirmed by a series of linear regression analysis where extremely high values of correlation coefficients are obtained among the examined variables: student's performance, invested mental effort and cognitive complexity.
Keywords: *cognitive complexity, problem solving, chemical technology*.

Introduction

Although the problem of unpopularity of chemistry often lies in old teaching methods with the absence of laboratory exercises in primary and secondary schools (Woldeamanuel, Atagana & Engida, 2014), understanding of chemical concepts at three levels of representation (Chiu, Chou, & Liu, 2002), one of the most important causes of this phenomenon is that the students of chemistry do not have direct contact with its application in a real environment or industry (Lundgren, 2006). This is especially noticeable among students of chemistry and related disciplines. They come into contact with a larger number of laboratory work at university. Many of them have the problem because theoretical knowledge has already been adopted and it is difficult to integrate theoretical knowledge with the practical application of the learned chemical processes. After the industrial revolution, which is considered the beginning of the development of chemical technology, it became necessary to transform simple, applicable practical (crafted) knowledge into science-based learning, especially for the high technological education needs (Lundgren, 2006). Due to the contribution that chemical technology has in the production of useful materials and the development of efficient technologies that serve both the individual and society as a whole, the utmost importance is to implement knowledge of chemical concepts and processes through education (Hofstein & Kesner, 2006). Chemical technology is in touch with many scientific disciplines such as economics, physics, mathematics, cybernetics, applied mechanics, environmental protection and other technical sciences. Because of this kind of the correlation, chemical technology possesses a special challenge in terms of dimensioning the complexity of its problem tasks, since they may contain several different concepts from different subjects.

As a reliable method for calculation of the rating of cognitive complexity of tasks, mostly because the subjectivity of experts is reduced to the minimum, is a method developed by Knaus, Murphy, Blecking and Holme (2011). The Rubrics for the rating of the cognitive complexity of the problems, such as this specifically designed for this method, need to be created wherever possible for different fields of chemistry as well as for different levels of education. In other words, it is necessary to implement as many of its adaptations as possible with detailed and additional analysis of basic concepts and additional concepts that are specific to a specific subject.Various Rubrics have been developed for assessment of the cognitive complexity of chemistry problems (Knaus et al., 2011; Raker, Trate, Holme, & Murphy, 2013; Horvat, Segedinac, Milenković, & Hrin, 2016; Horvat, Rodić, Segedinac, & Rončević, 2017). Cognitive complexity calculated using Rubrics in all cases is highly correlated with students' achievement and students' invested mental effort. Reserach aim of this paper was to create and validate a method for the assessment of cognitive complexity of chemical technology problem tasks.

Research Methodology

General Background

As the specificity of the chemical technology problems largely inlude mass balance with and without chemical reaction, as well as energy balance, these domains were the basic concepts represented in the Table for assessment of concept difficulty. By estimating the difficulty of the concepts represented in the problem (easy, medium and hard), the Table for estimating the difficulty of concepts and their interactivity was created for chemical technology problems, using the method from Knaus et al.(2011) where the numerical rating of the cognitive complexity of the problem was calculated.

Sample Selection

The total sample of this research consisted of two classes of chemistry students at the Department of Chemistry, Biochemistry and Environmental Protection, Faculty of Sciences, Novi Sad, Serbia. Students of these classes according to the curriculum of the Faculty of Science study the subject of Chemical Technology at the second or third year of their studies (basic academic studies in these classes last 4 years).

Instrument and Procedures

The test with five tasks was designed as a research instrument for the purpose of this research. Each correct task was evaluated with one point, so the maximum score on the test was 5 points. The numerical rating of the cognitive complexity of the tasks was in range from 1 - 5. Besides the achievement, assessment of the invested students' mental effort for each student was measured. For these purposes, a 5-point Likert scale was used.

Data Analysis

The obtained data were analyzed using Statgraphics Centurion XVI and IBM SPSS Statistics 22 software programs.

Research Results

The test showed a good reliability which was calculated as a measure of internal consistency and expressed as a Cronbach α coefficient. The test was moderate difficulty level (the average achievement is 1.86 / 5) and the excellent index of discrimination (0.62 for achievements and 0.70 for mental effort).The average value of the mental effort on the test was 3.32 which means that the test is not difficult or easy on the 5-point Likert scale.

Information about the validity of Rubrics for the cognitive complexity rating was obtained by combining the measures of students' achievements and the measure of the investeded mental effort. In order to validate this procedure for the assesment of cognitive complexity of chemical technology problems, the existence of statistically significant correlations between students' achievement and cognitive complexity of the problem, students' invested mental effort and cognitive complexity, as well as student achievement and invested mental effort. High correlation coefficients were obtained: -.61 for dependence achievement - mental effort; -.46 for dependence achievement - cognitive complexity and .58 for dependence mental effort- cognitive complexity). The procedure was validated with statistically significant correlations.

Conclusions and Implications

With optimization of the cognitive complexity of the tasks, which means specially designing the Rubric for the assessment of the cognitive complexity of tasks in chemical technology, the requirements for information processing are reduced and in this way it affects on better students'achievement with a minimal mental effort. Based on the obtained correlation coefficients, there is shown that with increasing of cognitive complexity of the problem, the students use more resources of working memory, and therefore invest a higher mental effort to solve the task and have lower achievement that is in accordance with the results previously obtained. As a possibility of application can be distinguished to create other Rubrics in different domains, as well as validation of these Rubrics by another method. Also, a wide range of complex problems can be created in chemical technology, which requires skills and concepts needed to solve them, such as a large number of concepts of thermodynamics, the process streams and others.

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THE PUBLIC UNDERSTANDING OF EMERGING TECHNOLOGY IN EAST TAIWAN AREA: AN EXAMPLE OF NANOTECHNOLOGY

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Abstract

The purpose of the research was to understand the public's social Image of emerging technology—nanotechnology. Furthermore, the differences among different major students and the decision-making style in "self-evaluation and other-evaluation" were analyzed too. In this research, the social image was defined by three phases, "general image of nanotechnology", "business decision behavior of nanotechnology", and "free recall of nanotechnology". The research instrument was a self-designed questionnaire "college student' social image of nanotechnology". The participants were 256 college students selected using convenience sampling from one university in the east Taiwan area. The main findings were: (1) Students tended to agree that nanotechnology is better than other general-tech. (2) The college students believed that they have more rational attitude and behavior to make decision than others. (3) Most college students' association related "nanotechnology image" with "high tech" in thinking.
Keywords: *nanotechnology image, public understanding, social image.*

Introduction

Nanotechnology seems to be an important emerging technology in contemporary society. From the position of education, modern civil should have the competencies of nanotechnology. College students will become new members of the society in the future. They received information of nanotechnology from many ways, such as formal curriculum and mass media. So, the social image of the emerging technology is indeed a concerned issue in modern society. The purpose of the research was to understand college students' social Image of emerging technology. The nanotechnology was selected as the target of emerging technology. Beside the social image of nanotechnology that was studied by college students, the differences among different major students and the decision-making style in "self-valuation and other-valuation" were analyzed too.

Research Methodology

In this research, the social image was defined by three phases, "general image of nanotechnology", "business decision behavior of nanotechnology", and "free recall of nanotechnology". Based on the definition of social image above, the research instrument was a self-designed questionnaire named as "college student's social image of nanotechnology, CSSIN". The instrument "CSSIN" was designed as Likert's four-point rating scale. The reliability of phase "general image of nanotechnology" was Cronbachα.77, and was .83 for "business decision behavior of nanotechnology". The instrument content was based on expert validity by three professionals. One is a scientist, one a science educator, and one a senior teacher.

The participants were 256 college students selected from one university in the east Taiwan area. All participants were categorized as two groups by their majors–science-major group (SMG) and non-science major group (NSMG). The data was analyzed by descriptive statistics and *t*-test for significant difference.

Research Results

Phase 1: General Image of Nanotechnology

The college students' general image of nanotechnology was shown as table 1. Only the mean of sub-category 3 was lower than 2.5 and the mean of sub-category 1 and 2 were higher than 2.5. So, students tend to agree that nanotechnology was better than other general-tech, and the products of nanotechnology were better than others too. Besides, college students think that people choose nanotech products does not mean that she or he has a better understanding of nanotechnology.

Table 1. College students' general image of nanotechnology.

Sub-category	Items	*M*	*SD*
The high-tech superiority of nanotechnology	The efficacy of nanotechnology product is often superior to the general technology products.	2.84	.571
	Nanotechnology products will be relatively easy to use.	2.68	.588
	The efficacy of nanotechnology product will last longer than the general technology one.	2.62	.614
	To label nanotechnology on the product is helpful to improve the value of the commodity.	3.15	.642
	Nanotechnology products is a high-tech.	3.14	.645
	Subtotal	2.89	.419
The possible development of nanotechnology in the future	Nanotechnology is amazing, it makes life more comfortable and convenient and secure.	2.84	.602
	Extensive application of nanotechnology can solve many problems in the world	3.02	.632
	Continue the development of nanotechnology in the medical field, some terminally ill can be treated by nanotechnology in the future	3.03	.694
	Subtotal	2.96	.483
The understanding and consumption about nano-technology product	People choose nanotech products mean that she or he has a better understanding of nanotech-nology	2.12	.765

Phase 2: Business Decision Behavior of Nanotechnology

College students' business decision behavior of nanotechnology was shown as table 2. In addition to item 6, there were significant differences between the other items. It revealed that the college students didn't exclude the purchase of nanotech products, but they believe that they had more rational attitude and behavior to make decision than the others performed.

Table 2. College students' business decision behavior of nanotechnology.

Item number	Evaluating myself on business decision behavior of nanotechnology / Evaluating others on business decision behavior of nanotechnology	*M*	*SD*	*t*-score
1	When the prices of products were the same, I would choose the nanotechnology products first.	2.88	.609	6.303**
	When the prices of products were the same, other people would choose the nanotechnology products first.	2.59	.620	
2	I would choose to have the same functionality of nanotechnology products even if the price was higher.	2.27	.556	-2.226*
	Other people would choose to have the same functionality of nanotechnology products even if the price was higher.	2.37	.586	
3	I think that the products of nanotechnology must be better than the normal ones.	2.14	.568	-7.362**
	Other people think that the products of nanotechnology must be better.	2.47	.625	
4	I think nanotechnology merchandise is sold better than general merchandise.	2.55	.684	-2.458*
	Other people think nanotechnology merchandise is sold better than general merchandise.	2.66	.643	
5	When I want to buy something, I will choose the product of nanotechnology in particular.	2.19	.591	-4.879**
	When other people want to buy something, they will choose the product of nanotechnology in particular.	2.39	.609	
6	The recommendation of friends and relatives will increase my willingness to buy the product of nanotechnology.	2.69	.628	-1.124
	The recommendation of friends and relatives will increase other people's willingness to buy the product of nanotechnology.	2.74	.618	
7	Advertising or shopping station sales will increase my willingness to buy the product of nanotechnology.	2.20	.675	-7.574**
	Advertising or shopping station sales will increase the other people's willingness to buy the product of nanotechnology.	2.54	.662	
8	Artist or expert endorsements will increase my willingness to buy the product of nanotechnology.	2.22	.773	-6.752**
	Artist or expert endorsements will increase the other people's willingness to buy the product of nanotechnology.	2.54	.691	
total	Evaluating myself on business decision behavior of nanotechnology	2.39	.406	-5.439**
	Evaluating others on business decision behavior of nanotechnology	2.54	.461	

* $p < .05$, ** $p < .01$

Phase3: Imagination about Application of Nanotechnology in the Future

College students' imagination about application of nanotechnology in the future was shown in table3. The medical application was most students' imagination (54.70%). Articles for daily use, cosmetic and skin care products were the second and the third. (19.9%, 14.50).

Table 3. College students' imagination about application of nanotechnology in the future.

Imagination about application of nanotechnology in the future	All Subjects (*N=256*)		Science-major (*N=115*)		Non-Science-major (*N=141*)	
	number	percentage (%)	number	percentage (%)	number	percentage (%)
Medical	140	54.70	62	53.90	78	55.30
Articles for daily use	51	19.90	13	11.30	38	27.00
Cosmetic and skin care products	37	14.50	11	9.60	26	18.40
Manufacturing of computer and electronics	31	12.10	12	10.40	19	13.50
Manufacturing of materials	21	8.20	12	10.40	9	6.40

Conclusions

The main findings were: (1) Students tend to agree that nanotechnology is better than the other general tech, so the products of nanotechnology are better than others too. (2) The college student didn't exclude the purchase of nanotech products, but they believe that they have more rational attitude and behavior to make decision than others. (3) Most college students' association relate "nanotechnology image" with "high tech" in thinking. There are slightly different image associations with" nanotechnology R & D "and "nanotechnology sales" staff in thinking. And the "internet websites" was the best resource for the most college students to get the information of nanotechnology and its products. (4) There was no significant difference between science-major and non-science major students of "nanotechnology general image" and "nanotechnology business judgment behavior". However, the science and engineering department student association "nanotechnology image" and the application of future suspect in thinking tend to use scientific expertise, and the non-science major students tend to use general knowledge or intuition.

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THE CONSTRUCTION ACTIVITY AS A METHOD OF POLYTECHNIC AND SCIENCE LEARNING

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Abstract

The research orientation of the Department of technics, Faculty of Education, University of Hradec Kralove focuses on finding new ways for development of polytechnic and science education. The research is motivated by the fact that children's interest in technical and science subjects is decreasing in recent years in the Czech Republic. The research aims are to prove the applicability and effectiveness of multidisciplinary methods in teaching of technical and science subjects. The research observed the effect of the use of construction activity in teaching of physics in lower secondary school. The results of research confirmed that working and construction activity can develop technical and science thinking of children.
Keywords: *polytechnic education, science education, lower secondary school, construction activity, construction kit.*

Introduction

The issue of polytechnic education is discussed in the Czech Republic. Insufficient number of technically skilled experts is available in the Czech Republic. Young people are not interested in technical fields and technical areas. "The education system of the Czech Republic underestimates in the long-term polytechnic education" (Inovační strategie České republiky 2019–2030, 2019, p. 8). A number of documents, such as the Ministry of Industry and Trade of the Czech Republic "Industry 4.0 Initiative" (Národní iniciativa Průmysl 4.0, 2015, p. 10) or the documents of the Council for Research, "Innovation Strategy of the Czech Republic" (Inovační strategie České republiky 2019–2030, 2019, p. 8) draw attention to the need to improve polytechnic education. The Innovation Strategy of the Czech Republic 2019–2030 (Inovační strategie České republiky 2019–2030, 2019, p. 8) emphasises "There is a lack of a sophisticated STEM system (Science, Technology, Engineering and Mathematics), which is one of the key competencies within the new curriculum concept from nursery schools through primary education to secondary education. There is clear absence of a compulsory subject focused on technology in the lower secondary schools (development of technical thinking, practically applicable skills, fine motoric skills and technical creativity) with a link to new technologies" (Inovační strategie České republiky 2019–2030, 2019, p. 8).

Solution of the problems of current society requires interdisciplinary and multidisciplinary approaches. This approach is neglected in the Czech education system. The education is provided in separate subjects such us Mathematics, Physics, Chemistry, Biology etc.

The research aims of the academic workers of Department of technics, Faculty of Education, University of Hradec Kralove is to design activities for primary school second graders and the development of technical and scientific thinking, kids' practical skills and technical creativity. One of the possibilities is to use construction kits - construction models in lower secondary school education. The construction model approximates real phenomena, events and objects with greater accuracy than, for example, a graphical model. Modelling is a multidisciplinary activity in which knowledge from mathematics, physics and technology is involved.

The research aims were:

1. Design a construction model that the kids at lower secondary school could construct and demonstrate the physical phenomenon;
2. Monitor construction activity and find out whether the construction activity helps to develop physics thinking of the lower secondary school learners.

Research Methodology

Using a structural model, the dependence of centripetal force F_d of a solid in circular motion on other mechanical quantities - mass *m*, radius of circular motion *r*, angular velocity *ω* was demonstrated. For the purpose of the experiment the Fischertechnik kit (https://www.fischertechnik.de/en) was used. Learners constructed a model of carousel according to the instructions in the kit. The carousel was driven by an adjustable speed electric motor by means of gears. Totally 53 (28 girls and 25 boys) kids from the eighth grade of lower secondary schools participated in the experiment. The motivation was as follows: "We all know the chain carousel. Some of you went on it yourself. What happens with the seats on the carousel when the carousel starts to rotate?"

During construction the kids were observing the model. The design skills and ability to navigate the instructions and skills of boys and girls were followed.

After building the model, the kids changed the length of the carousel (radius of circular motion *r*), changed the mass of the weights at the end of the arm (*m*) and the angular velocity of the carousel (*ω*).

The uniform circular motion is the simplest circular motion. Uniform circular motion is characterized by constant angular velocity *ω*. The angular velocity can be expressed as:

$\omega = 2\pi/T$, where *T* is period.

The circular motion is caused by centripetal force. Centripetal force F_d is proportional to centripetal acceleration a_d ($F_d \sim a_d$).

The centripetal acceleration is expressed as:

$a_d = rw^2$, where *r* is the radius of the circular motion.

The centripetal acceleration is therefore proportional to the radius *r* and the square of the angular velocity *ω*.

Presented construction model enabled:

- change the size of the angular velocity ω by changing the rotational speed of the motor that drives the carousel;
- change the radius of the circular motion r by changing the length of the hinge;
- change the weight m of the body by changing the weights.

Although physics at lower secondary schools does not introduce quantities and relations describing circular motion, children often encounter the movement of the circle in the technique - turning the wheel on the shaft, circular motion of the rotors in the electric motors, moving the grinding wheel on the electric grinder, moving the circular saw, etc.

With regard to the possibility of changes of above-mentioned quantities, the construction model allowed monitoring the dependence of the centripetal force F_d on given quantities qualitatively as well as quantitatively. As already mentioned, the movement of a uniform circle was introduced in the lower secondary school only informatively, without quantities and formulas, the dependence of centripetal force on other quantities can be studied only qualitatively.

During the experiment, the kids wrote in the table the values of the radius of rotation r, the angular velocity ω (given by the speed of the motor), the weight of the mass m on the strings, the value of the hinge length l and the angle of deflection at the movement α. The deflection angle was determined by a video of a moving carousel. The video was stopped at the point where the hinge deflection was the greatest. The angle was measured by a protractor directly on the monitor. The children determined on which quantities the angle of deflection of the carousel hinge depended or did not depend by processing the values of the quantities in the table. The angle α of deflection of the hinge was proportional to centripetal force F_d. Regarding the level of knowledge of lower secondary school learners, the dependency could be determined only qualitatively (Hubálovská, 2018).

Based on the table with measured values, the kids were asked a few questions to find out if they had understood the centripetal force – see Table 1 – Results of a questionnaire

Research Results

The example of the construction model of the carousel created by kids during construction activity is shown in the Figure 1.

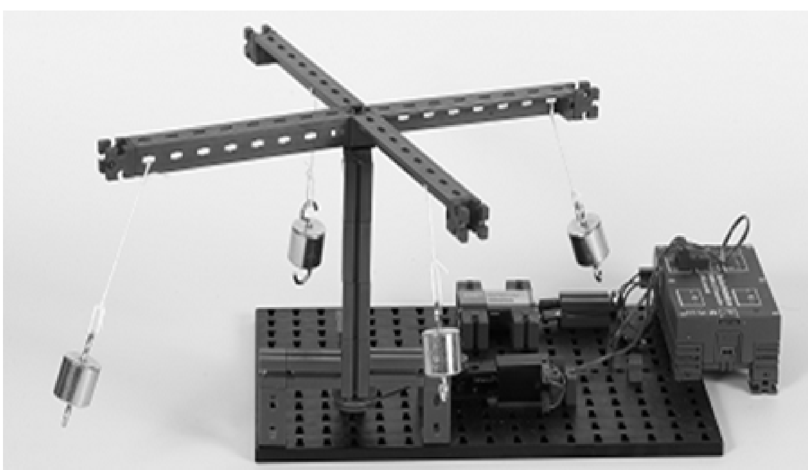

Figure 1. The example of the construction model of the carousel (Hubálovská, 2019).

The differences between girls and boys when working with the construction kit during the construction activity were monitored. The ability of boys and girls to navigate the manual, the ability to work systematically, and to observe the skill of boys and girls were followed. Significant difference between the boys and girls in the monitored areas was not found. Some girls, after studying the manual, first found all the parts to build the model and only then began construction. Almost all kids were able to construct a construction model. Sometimes some of them needed some advice. The biggest problem was with the involvement of the carousel drive.
Results of a questionnaire among children who carried out construction activities and experiments are presented in the Table 1.

Table 1. Results of a questionnaire.

	YES [%]	NO [%]
Does the hinge angle depend on the hinge length?	78	22
Does the hinge angle depend on the mass of the weights?	15	85
Was the largest angle of hinge deflection at the smallest circular speed?	7	93
Do you consider working with the construction kit useful?	89	11
Were you interested in the lesson with the construction kit?	68	32

Conclusions and Implications

The following findings emerged from the pilot educational experiment. Working activities with the construction kit is attracted and entertained for boys as well as girls. There are no significant differences between the girls and boys when working with the construction kit, both of the monitored groups are able to orientate themselves in the instructions and are able to build a model of the carousel. More boys than girls consider the kit to be useful.

Furthermore, the results of the questionnaire discover that experimenting with the created model of the carousel enables the learners to qualitatively understand on what quantities the centripetal force of the circular motion depends.

In this experiment, the kids used both manual dexterity, computer and video technology and naturally acquired physical knowledge. The present time requires a multidisciplinary approach in education. The combination of science and technology curriculum at lower secondary schools seems to be the possible way to develop learners' interest in technical and scientific disciplines.

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A DESCRIPTIVE ANALYSIS OF PRESERVICE TEACHERS' OPPORTUNITIES TO LEARN TO TEACH SCIENCE USING ICTS IN SOUTH AFRICA

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Abstract

Research suggests that there is not enough integration of Information and Communication Technologies (ICTs) into subject teaching by graduate teachers across a variety of school settings. This points in part to the inadequacy of preservice teacher preparation. Hence, this research explores the question of how preservice teachers develop the necessary competence to teach, particularly science subjects, using ICTs, by examining the opportunities to learn (OTLs) that are provided at three different South African universities.
Keywords: *ICT, opportunities to learn, preservice teachers, science teaching, teacher education.*

Introduction

Among the many issues related to the successful use of Information and Communication Technologies (ICTs) to teach in the classroom, the more salient one is on the training of preservice-teacher education students to teach specific subjects with these modern technologies. A recent study by Aslan and Zhu (2018) on social studies, mathematics and science beginning teachers' integration of ICTs addressed this issue and points to the need for changes in curriculum and assessment systems. Hennessy, Ruthven and Brindley (2005) have made a similar argument on the challenges of ICT integration in English, mathematics and science subject teaching and were concerned by the lack of training of teachers to use ICTs for specific subject teaching. ICT integration has been used in schools as an innovative way to address the challenges facing the quality of teaching and learning in schools, yet the take-up in the use of ICTs to improve learning is itself still very low. Some researchers have referred to the source of the problem as the inadequacy of teacher education, particularly in the way preservice teachers are provided with opportunities to learn (OTLs) and develop competence in the use of ICTs for teaching their subject matter (Cogan & Schmidt, 2015; Hebard, 2016, Schmidt, Cogan, & Houang, 2011). These researchers have argued that a lack of ICT integration in teacher preparation programmes makes it difficult for preservice teachers to use ICTs to teach curriculum subjects in schools after graduation (Baran, Canbazoglu Bilici, Albayrak Sari, & Tondeur, 2019; Gülbahar, 2008). As ICT integration continues to play an important role in education, teacher education programmes are expected to produce innovative preservice teachers that can adapt to different teaching and learning environments and who are able to use different ICTs for content teaching. Without such OTLs in the teacher preparation programmes, the use of ICTs for subject teaching by graduates from the various teacher education programmes will continue to remain a random occurrence that depends on a combination of innate abilities, opportunistic circumstances and/or the disposition of each college and/or university graduate.

Conceptual Framework

Previous studies that have drawn on OTL as a conceptual framework studied both in- and preservice teachers' development of competence to teach specific subjects. Some scholars have drawn attention to the relationship between OTL and competence to teach specific subjects by preservice teachers (Cogan & Schmidt, 2015; Hebard, 2016; Schmidt et al., 2011). These studies have demonstrated that preservice teachers' OTLs are determined not only by the number of courses taken, but also by the nature of the field experiences provided for them to practise the required skills. The current research is aimed at exploring how preservice teachers develop the necessary competence to teach science subjects using ICTs, thus unpacking the opportunities embedded for preservice teachers to learn to use ICTs during their university-based experiences. The "university experiences" (which define the coursework or modules on offer) and "school-based experiences" (which refer to teaching practice or work-integrated learning experiences) are two of the key contributors to preservice-teacher competence and thus define to a significant extent their OTLs. Hence, they need to explore them by examining the following research question: How can OTLs use ICTs to teach science be understood and explained?

Research Methodology

General Background

Data were drawn from a larger, concurrent mixed methods-design study (Johnson & Onwuegbuzie, 2004; Creswell & Creswell, 2017) using the Technological Pedagogical Content Knowledge (TPACK) questionnaire, document (lesson plan) analysis and semi-structured interviews. However, the focus for this study is on data from the TPACK questionnaire. This method was considered appropriate because it enabled the researchers to unpack the opportunities that a larger sample of preservice-teacher education students have for learning to teach science using ICTs.

Sample Selection

The research sampled four (4) randomly selected university-based teacher education programmes from three universities in close proximity to the researchers' place of work and which represent the range of standard teacher preparation programmes across South Africa. The sample composed of 153 participants representing all the final year science preservice-teacher education students, with specialisation in either physical sciences, natural sciences and/or life sciences. One of the universities has two programmes presented at separate locations, one urban (n=51) and the other rural (n=37), with the other two universities (n=31 and n=34, respectively) both located in urban settings. Among the three universities, one is a historically white university, another is a university of technology, while the third is a relatively new post-apartheid university.

Instrument and Procedures

A modified TPACK questionnaire was piloted to ensure reliability and validity (Schmidt et al., 2009). The adapted version of the TPACK questionnaire for preservice teachers was used to map out preservice teachers' OTLs to teach science using ICT knowledge and skills.

Ethical Considerations

Permission to conduct the study was sought from the research ethics committees at each of the four selected research sites. The researchers explained the purpose of the study to the participants, informed them that participation was strictly voluntary and that their responses would be kept confidential. Pseudonyms were used to protect the names of the institutions and participants (Creswell, 2017; Yin, 2014).

Data Analysis

Data were generated from a 5-point Likert-scale questionnaire administered to all 153 participants across the four research sites. Nine (9) items specifically measured the OTLs provided to the participants at each site. Six (6) of these items specifically refer to structured opportunities that are part of the teacher education programme at each site. Of these six, the first item probed whether the participants have completed a "computer-related module" as part of their teacher education programme. In this item, the response option was either a "yes" or "no". The next five items investigated the extent to which the participants attributed their learning about the integration of ICTs for teaching and learning to various sources and/or opportunities: viz. "computer-related education module" on offer at their campus; "exemplary practices from their science education lecturer"; "exemplary practices from their ICT-related education module lecturer"; "exemplary practices from any of the other education lecturers"; and, finally, from "mentor-teachers" who supervised them during teaching practice. Descriptive and inferential statistical techniques were used to analyse the data.

Research Results

Table 1 presents the descriptive analysis of the frequency counts for the six items that measured participants' OTLs. The positive responses of "agree" and "strongly agree" were aggregated to give a frequency count for each preservice-teacher participant. The total number of participants at each site and their aggregate response (agree and strongly agree) for each of the six items are displayed below.

Table 1. Number of participants (frequency counts; n) identifying specific OTLs at the different university campuses or programme sites.

Campus (**University**) ***(pseudo-nyms)***	Item 1: Curriculum includes a computer-related module (%)	Item 2: Learning to use ICTs from one or more university module(s) (%)	Item 3: Learning to use ICTs from a science education lecturer (%)	Item 4: Learning to use ICTs from an ICT-related education module (%)	Item 5: Learning to use ICTs from another education module lecturer (%)	Item 6: Learning to use ICTs from a school-based mentor teacher (%)
Knowledge (Urban)	53 (*n*=27/51)	71 (*n*=36/51)	45 (*n*=23/51)	37 (*n*=19/51)	51 (*n*=26/51)	39 (*n*=20/51)
Knowledge (Rural)	70 (*n*=26/37)	81 (*n*=30/37)	46 (*n*=18/37)	41 (*n*=16/37)	44 (*n*=17/37)	36 (*n*=14/37)
Diamond	85 (*n*=29/34)	59 (*n*=20/34)	59 (*n*=20/34)	47 (*n*=16/34)	56 (*n*=19/34)	41 (*n*=14/34)
Goldfields	94 (*n*=29/31)	77 (*n*=24/31)	61 (*n*=19/31)	65 (*n*=20/31)	61 (*n*=19/31)	42 (*n*=13/31)

Table 1 shows that participants at all the sampled teacher education sites seem to have access to one or more computer-related module(s) designed to broaden access to ICT skills. While such modules are useful for skills development, they are hardly adequate to support the use of ICTs for teaching and learning specifically. Documentary evidence suggested that at all research sites, the “computer-related module” was a skills module that focused on the use of Microsoft Word and Excel and other Microsoft programmes. Interestingly though, only about half of the participants at the rural Knowledge university even had access to such a module(s). This was in spite of the confirmation by the majority of the participants that they learn most of their ICT skills from a “university module or class”. In instances where only about half of the participants seem to have access to such a university module, their OTLs might thus be limited, unless a structured intervention is provided for in the curriculum. The last column in Table 1, on whether participants learned to use ICTs from a school-based mentor, clearly shows aggregate counts of less than 50% for all the cases studied. This finding was a surprise and should be a cause for concern for teacher education in general given the major expectation for teaching practice to provide a platform for preservice teachers to put into practice and try out some of their learning and skills in the context of a real classroom.

Conclusion and Implications

This research has established that the distribution of OTLs to use ICTs for teaching science varies across and within programmes. Furthermore, the findings also suggest that school-based experiences may lack in terms of OTLs to teach science using ICTs. There is no better opportunity for preservice science teachers to learn to integrate ICTs into the teaching of science in schools than by doing it under supervision and careful guidance in the schools during teaching practice. With the missed opportunities as described in this paper, it should thus not be surprising that most preservice teachers and/or other beginning teachers continue to struggle to integrate ICTs into the teaching and learning of their subjects.

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DATA MINING IN EDUCATION: ONLINE TESTING IN LATVIAN SCHOOLS

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Abstract

The new research results on the online- testing method in the Latvian education system for a learning process assessment are presented. Data mining is a very important field in education because it helps to analyse the data gathered in various researches and to implement the changes in the education system according to the learning methods of students.
The aim of the research was to analyze how much time students devote to each task depending on the task type and the cognitive activity level in the online national test.
Research methods: 1) analysis of scientific literature; 2) descriptive statistics and dependency analysis for processing the data.
Research results showed that the time spent on tasks depends not on the complexity of the task but on the form and formulation of it.
Keywords: *online test, data mining, cognitive actitity level.*

Introduction

Nowadays, with the growing attention to educational data mining, it is important to use the possibilities provided by technologies - like data gathering and data analysis in a new level to use the results in order to improve the learning process. The aim of Diagnostic tests is to find out students' basic skills acquisition on finishing a certain level of education according to the national education standards and the subject curriculum requirements. For the last three years, schools in Latvia have the choice of how to take Diagnostic tests, either in online or paper form. The choice is made by the school itself, in accordance with its capacities and needs. Diagnostic online and paper tests take place simultaneously (VISC, 2015). For two consecutive study years (2015/2016 and 2016/2017), research has been carried out whether it is possible to carry over Diagnostic tests from one environment into another one, by maintaining the same content, task functions, and other testing elements. On Diagnostic test results at the basic school level, the study was performed in Natural Sciences and at the secondary school level in Physics and Chemistry (Jonane, &Dzerve, 2016, Cabelis, 2015; Juskaite, 2019). The study indicated that there was no statistically significant difference between the obtained data. (Juskaite, 2018). The issue is to understand whether the unanswered question means the lack of student's knowledge or inability to comprehend the gist of the question. For example, students are used to study in the traditional way (from books and papers), and later they are required to take their tests online, or vice versa, studies that have been carried out by using a tablet or a computer are requested to take a test in paper format. In both cases, the student experiences are in a completely contrasting situation (Juskaite, 2018). For instance, a piece of paper can be turned over, but online testing means looking to the screen and using the scrollbar. Obviously, it is rather complicated to answer the question when one has to switch between the extracts or refer to a passage having been exposed to earlier. The questions are identical to the ones on paper format, but the presentation of it is sufficiently different. The relevance of the question of whether it is essential to practice within the environment that the test is being carried out is recently increasing. The benefit of saving paper and other resources has been highlighted so far, but students remain at the centre of the focus. The individual growth, development of new skills and competencies, purposeful guidance of a learner towards modern society and lifestyle should be considered equally important (uzdevumi.lv, 2017). Online learning has a rapid entrance in training environments, therefore, it is essential to characterise the changes brought along. During the analysis of students' behaviour, it was possible to identify risks and to seek solutions. It allows to trace trends and plan development much more effectively (Attali & Tamar, 2000; Huberman, Bitter, Anthony, & O'Day, 2014; Kehoe, 1995; Sočan, 2009). Although many tasks or problems in the educational environment have been managed or resolved through the knowledge of the way how students solve exercises of various type, it is important to continue the research on student behaviour in the online environment (Deshpande, 2017; Daugule & Kapenieks, 2019). The content of the tasks was developed by the National Centre for Education, and the online environment was provided by uzdevumi.lv.

Research Methodology

This is the first attempt in the Latvian education system where the research of student time investment is considered in each type of tasks depending on levels of cognition and task types. The main aim of the research was to analyse how much time it is necessary for the students to complete each task depending on levels of cognition and task types. For this research data mining technique has been used. The analysis of the research data was carried out using Classical Test Theory (CTT) and Test Analysis Program ITEMAN™ for Windows. The figures and tables were created using MS Excel and Tableau Public 10.4.2. A student completed 30 tasks online. The tasks had different levels of difficulty and response types (multiple choice, fill in the missing word, explain the choice in written form). The 22 tasks of the test were evaluated automatically by the computer programme. The tasks where students had to enter a word (1, 13, 14, 23, 27 and 28) were partly evaluated by the system. If a student wrote one of the words matching those entered in the system, a point was granted; otherwise – all the imprecise answers were tested by a teacher, whose estimate on the applicability of the answer is important since a student might have made a spelling mistake in the response. Eight tasks of the test (5, 6, 7, 18, 19, 25, 29 and 30) were evaluated by a teacher online. When the evaluation of all student performances is completed, a teacher must click the "Checked" button at the bottom of the results page, and all the results are transferred to the National Centre for Education within an hour (VISC, 2018).

Research Results

During the 6th-grade diagnostic test in the last academic year (2017/2018), a time controlling mechanism was built in to indicate the time required for students to complete each of the tasks. The sequence of response types was also mixed; no multiple-choice answers were provided, but the students had to read and comprehend the gist of the provided answer. It is very difficult to perform this test if it is presented in a more traditional (paper format) way. The created system fixed and recorded the time spent on each task by every individual student. Since the test included tasks of various types and diverse levels of cognitive activity, the obtained data helped analysing the time used to complete each of the specified tasks and significantly affected the decision making. Since online and paper-based tests take place simultaneously, it is possible to analyse students' behaviour and other abilities as common changes in educational processes in Latvia. Diagnostic tests were chosen as a sample in order to ensure that changes will not affect the exam performance (VISC, 2017). This research analysed the achievements of students based on their skills, cognitive level and spent time. The results were obtained after compiling and processing the data. The average task performance in the country was about 64.91%. It demanded more time for students to complete the tasks with longer formulations of the exercises. Particularly long time was necessary for students to solve tasks that contained elements of research. Tasks that provided graphical information and icons were done quickly and accurately by students. The diagram (Figure 1) shows that these results are appropriate and require less time to perform the task.

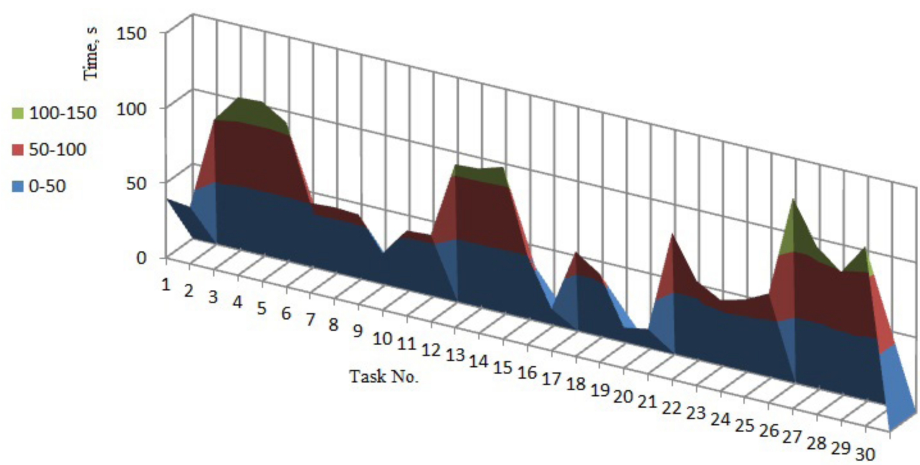

Figure 1. Time for each task (average).

The time spent on tasks depends not on the complexity of the task but on the form and formulation of it. Almost 20% of the students could not fulfil all the tasks in the required time, 14% of the students completed only 18 tasks with multiple choice but did not answer to the other questions even though they had enough time for it. If we compare the results with cognitive activity levels, we can clearly see that the longest tasks were dealt with first and third cognitive activity levels, while the lowest time cost was in the second cognitive activity level, despite the fact that there was a lot of text in the wording of the tasks. The time spent on tasks depends not on the complexity of the task but on the form and formulation of it. Almost 20% of the students could not fulfil all the tasks in the required time, 14% of the students completed only 18 tasks with multiple choices but did not answer to the other questions even though they had enough time for it.

Conclusions

The number of participants in total was large enough ($N = 5794$) to draw objective conclusions about students' knowledge and skills.

The tasks with a lot of text in the wording demanded more student time. The particularly long time was necessary for students to solve tasks that contained elements of research. Tasks that provided graphical information and icons were done quickly and accurately by students.

In conclusion, the time spent on tasks depends not on the complexity of the task but on the form and formulation of it.

During this academic year, the research is continued by observing other aspects and analysing new situations. As a future intention is to enrich it by encompassing more user behaviour cognitive functions, which will allow getting the results on how exactly learners react to each type of tasks.

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MAGNET AND ITS APPLICATION. PHYSICS EDUCATION IN KINDERGARTEN

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Abstract

It is generally accepted that education in the field of physics is possible only when one has received sufficient grounds for it. But physics is an attempt to understand the world around us. Everything one needs to study physics is an open mind and willingness to learn. It is also commonly thought that preschool-age children have a natural curiosity to figure out how the world functions. They focus not only on people but also on objects which they touch, taste, smell, throw into water, etc. Therefore, physics may be introduced as early as in kindergarten. Experiments in physics conducted together with a preschool group activate all analyzers, facilitate a more complete understanding of curricular contents, allow children to discover answers independently and to formulate conclusions. The research presents theoretical considerations regarding the nature of the class of physics conducted with preschool-age children and examples of practical solutions corresponding to physics-related activities performed in a group of 6-year-olds in the Self-Government Kindergarten at the School Complex in Łomazy.
Keywords: *natural curiosity, physics education, preschool education, 6-year-old child*.

Introduction

Physics seems very difficult to a number of people. Thus, it is generally accepted that education in the field of physics should be commenced when one has received sufficient grounds for it. As a regular class, physics is introduced in later years of the elementary school in Poland. But physics involves observation, conclusion drawing, model building, correcting incorrect conclusions drawn from observation, presenting phenomena which allow to notice the real picture of the physical world. Everything one needs to study physics is an open mind and willingness to learn. It is because physics is an attempt to understand the world around us. Therefore, physics may be introduced as early as in kindergarten.

The Nature of Physics Education in Kindergarten

It is commonly thought that preschool-age children have a natural curiosity about the world around. The best way to satisfy child's curiosity is to study physics. Research in physics constitute the foundation for multidisciplinary child development. The development of critical thinking skills, cause and effect thinking, comparing and generalizing, contribute to the broadening of children's intellectual horizons.

Experiments in physics conducted together with a preschool group activate all analyzers, facilitate a more complete understanding of curricular contents, allow children to discover answers independently and to formulate conclusions (Gerstmann, 1986).

Even though, experiments in physics seem difficult, they do provide the child with an opportunity to explore and investigate thoroughly the fascinating world of nature and technology. Knowledge and skills acquired in early childhood will become an inspiration and a bridge to gain knowledge at further stages of education. They will lead to new experiences and sensations and new knowledge the child may refer to at later stages.

Conducting Physics with Preschool-Age Children

Physics classes were conducted in the Self-Government Kindergarten at the School Complex in Łomazy by the students of Pedagogics specializing in early school education and preschool education.

Children completed the following topics: What do we need for the current to flow? What makes electric toys move? What are the features of a magnet? Can magnet attract through paper? How to use a compass? How to determine directions with the use of a compass? How to make a scales oneself?

The main aim of the activities was to stir children's interest in the world of nature and to teach them to conduct observations, draw correct conclusions from conducted experiments and physical phenomena.

General goals: To awaken an active interest and cognitive activity of the child. To develop technical interests. To pose and solve problems, see the cause and effect relations. To get to know simple physical phenomena by means of simple experiments. To initiate autonomous actions of children in the natural environment. To expand child's vocabulary by the addition of new terms. To follow the rules of cooperation during work.

Specific goals: To actively participate in scientific games (watch, seek, observe, compare, study, experiment). To wait patiently for one's turn to participate in research. To follow the set rules. To formulate reflections and conclusions. To use simple tools. To be able to correctly identify studied objects and phenomena. To be able to correctly identify technical equipment. To understand the reality in a cautious and open manner. To take care of the condition of the social and natural environment.

The research was related to a class focusing on a magnet and its application in a compass.

Experiment No. 1 What are the features of a magnet?

Aids: two magnets

Instructions for the child:

1. Bring the two magnets closer together with the poles colored blue. What can you feel? Do the magnets repel one another?
2. Bring the magnets closer together with the poles colored differently. What can you feel? Do the magnets attract one another?

Chat with the children: Every magnet, irrespective of its shape, has two poles, conventionally called the north and the south pole. The pole is the end of the magnet. It has been agreed that the north pole is to be colored blue. It is cold in the north and blue is the so-called cool color. The south pole is colored red. In the south, it is warm and red color is also "warm". The same poles (called unipolar) repel one another, different poles (opposite) attract one another.

Experiment No. 2 Can a magnet attract through paper?

Aids: cardboard box, paper clips (or other fine metal objects), magnet
Instructions for the child:
1. Put the paper clips or other fine metal objects into the carton box Note! A magnet does not attract coins.
2. Move the magnet underneath the carton box.
3. Watch what is happening to the clips in the carton box. Are they moving?

Chat with the children: Have you noted that clips are moving inside the carton box because of the magnet movements? Magnets can move metal objects and, as you have just seen, even the carton box cannot bother it. How can magnets be used in everyday life? (for example, magnetic boards, locks in the door, decorative magnets can be put on fridge doors, etc.)

At the end of the class the children took a test checking their knowledge of the way magnets work.

Experiment No. 3 How to use a compass?

Aid: compass
Instructions for the child:
1. Place the compass on a level surface.
2. Before you read the direction, move the compass shield around so that the north-south line is aligned with the needle. A specially marked north-pointing end shows the north.
3. Remember not to place the compass near any iron objects.

Chat with the children: Can a magnet show directions? The Earth is a giant magnet - it has a north and a south pole. Every magnet when freely hanging will point in the direction of the Earth's poles. This is used in compasses. Some compasses have a special clamp which locks the pointer (magnetic needle). You have to release the lock before using the compass for the needle to move freely.

Experiment No. 4 How to determine directions with the help of a compass?

Aids: compass, pencil, drawing pad
Instructions for the child:
1. Take a compass, a drawing pad and a pencil to the preschool yard.
2. Mark the place where you are on the drawing pad sheet, the way you see it on the picture.
3. With the help of the compass, determine where the north is and mark it on the sheet.
4. Now, draw what is to the north of your kindergarten.

Conclusions

All in all, attention should be paid to the role of the teacher in providing children with opportunities to explore the world around through an active and direct contact with both the world and its phenomena. The task of the teacher is more than to create conditions which stimulate the child's research activities and allow him/her unrestrained decision making related to independent problem solving. It is about teaching the child the art of precise observation with the use of one's senses, to create conditions for such precise observation, to shape the child's attention span (focus, interest, correct behavior), to support one in making appropriate notes and to adjust one's knowledge to perceptive abilities of the child. Furthermore, the teacher is to arise child's interest in his/her surroundings, stimulate his/her activity, to learn, to observe a selected object, to draw attention to details, and to motivate to think. Thus, physics should be offered in kindergarten as often as possible, and even more bearing in mind that teachers have many opportunities to broaden curricular contents implemented in accordance with the preschool education core curriculum.

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CALCIUM CYCLE IN CHEMISTRY TEACHING AT THE LOWER SECONDARY SCHOOL

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Abstract

The research is focused on the use of experimental calcium cycle in chemistry teaching at the lower secondary school. The cycle is based on four reactions: 1. thermal decomposition of calcium carbonate, 2. reaction of calcium oxide with water, 3. calcium hydroxide with hydrochloric acid, 4. reaction of calcium chloride with sodium carbonate. The calcium cycle was tested at lower secondary schools (and equal classes from comprehensive schools). Despite the difficulty of taking some steps, the cycle was accepted by both teachers and learners.
Keywords: *chemistry teaching, experimental cycle, calcium cycle, lower secondary education*.

Introduction

Experimental cycles are fewer common alternatives to organizing and conducting school experiments. They are based on the mutual transformations of chemicals, while the starting material of the cycle is also its final product. They are based on chemical transformations of inorganic substances as well as organic substances, they also take other forms, such as waste recycling. Cycles based on chemical transformations of inorganic substances are most used in teaching at the lower secondary school. In this context, a copper cycle, based on a series of copper and its compound reactions (Condike, 1975), has taken an important position in this field of school experiments. The cycle is attractive in terms of teaching, it is associated with significant colour changes in substances, changes in the reactant state and variety of reaction types, for example, acid-base reaction of oxidation-reduction etc. A certain disadvantage is the toxicity of some of the substances formed during the cycle. Experimental cycles have proved to be an interesting, less common way of presenting chemical transformations. They were subjected to further investigation in relation to their use in teaching thematic units of chemical reaction at the lower secondary school.

In this context, an experimental calcium cycle has been proposed as an alternative to the already used copper cycle. So far, little attention has been paid to calcium if it is in experimental cycles for teaching. For example, the calcium cycle in nature (Duesing, 1985), or processes associated with practical activities: limestone burning, lime slaking, mortar solidification (Luna Vera, Guancha Chalapud, Castillo Viveros, & Vasquez Medina, 2018, Royal Society of Chemistry, 2008). In this context, a simple cycle was designed based on four reactions. The starting compound was calcium carbonate. The first cycle step was thermal cleavage of calcium carbonate leading to calcium oxide. In a second step, calcium oxide was converted to calcium hydroxide by reaction with water. The third step – calcium hydroxide reaction with hydrochloric acid gave calcium chloride as the product, which in the fourth step reacted with sodium carbonate to calcium carbonate – the starting compound of the cycle (see Figure 1).

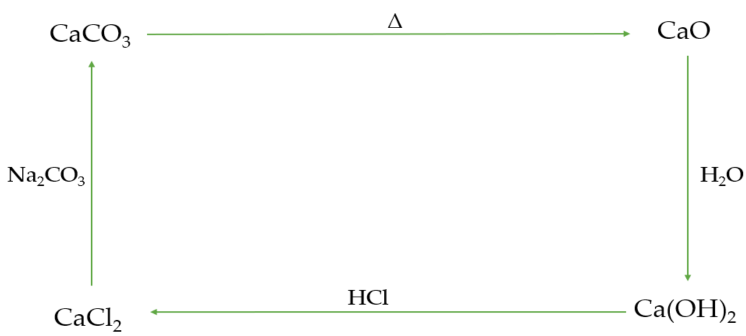

Figure 1. Diagram of calcium cycle.

The cycle is a multi-layered set of reactions that can be interpreted in several contexts. For example, the first and second steps symbolize the already cited technological processes (limestone burning and lime slaking), as well as reactions that occupy significant positions in terms of chemical reaction classification – chemical decomposition and chemical compounding. The next step of the cycle is chemical replacement, according to other criteria an acid-base reaction. The last step is a double exchange and from another point of view a precipitation reaction. The experimental cycle is based solely on changes in the state of matter – colourless solutions change to white precipitates and vice versa. Therefore, the experimental cycle is complemented by a series of tests relating to individual products, which are again mainly based on precipitation reactions. It is also necessary to measure pH, which accompanies all steps of the experimental cycle (Kolar, Bilek, Machkova, Rychtera & Chroustova, 2018). The main purpose of presented research is to verify the new module with the topic Chemical Reaction for teaching of chemistry at the lower secondary school.

Research Methodology

The experimental cycle of calcium was tested in chemistry education at the lower secondary school through methods of action research. Three teachers and 81 15-year old learners in four classes took part in the evaluation process of the calcium experimental cycle in March and April 2019. The evaluation of the results of the experimental cycle of calcium in teaching was mediated by teachers through their observations of lessons and through their group interviews with learners.

Research Results

The teachers' observations and their summarizing of results from group interviews with learners show that the experimental cycle was generally favourably accepted. The teachers had several comments to implement. Above all, it is the number of lessons, teachers believe that laboratory exercises cannot be fully realized during two lessons. Regarding the actual realization of the experimental cycle, the greatest difficulty appeared to be with the first step of the experimental cycle – thermal decomposition of calcium carbonate. The conversion of calcium oxide to calcium hydroxide was then only a routine matter. With some problems, the reaction of calcium hydroxide with hydrochloric acid was also associated with overdose. Teachers evaluate the complexity of the experimental cycle as a benefit, because it is not only related to conducting their own experiments, but relates to a closer understanding of different types of reactions, in conjunction with chemical nomenclature, chemical calculations, the way notes on the realization of experiment and the formulation of conclusions (protocols). Small problems were identified only on technical and material support of lessons realisation.

Conclusions

Experimental cycles in terms of pedagogy fully meet the requirements of the school experiment. The copper cycle, which carries security risks, was replaced with a cycle of calcium, which does not produce such significant colour changes but is safer and allows learners to perform experimentation. After verifying this cycle in chemistry teaching, despite all the difficulty of carrying out the experiment especially the thermal decomposition of calcium carbonate, it was accepted by the teachers and the learners with understanding. Teachers also pointed to the fact that conducting an experimental cycle teaches learners careful accuracy and responsibility in experimental work.

Acknowledgement

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METACOGNITIVE MODEL FOR DEVELOPING SCIENCE, TECHNOLOGY AND ENGINEERING FUNCTIONAL LITERACY

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Abstract

Technology and engineering functional literacy should be intentionally developed in the school system – like any other competence, it does not develop spontaneously. For this purpose, a didactic model, the Metacognitive model for developing technology and engineering literacy (McM_T&E), was developed, implemented and evaluated. The results of evaluation show that focusing on technology and engineering literacy in Technology and Engineering classes using the McM_T&E model increases students' technology and engineering functional literacy.
Keywords: *functional literacy, metacognitive model, science functional literacy, technology and engineering functional literacy*.

Introduction

The term functional literacy does not reflect the essence of competence any more, since in today's complicated world each scientific field has created a specific language and a specific way of structuring texts, in order to present knowledge about the world and its nature. A consequence of this is that the school system has to develop specific literacies, including science, technology and engineering literacy in the frame of STEM literacy. When reading expository and explanatory texts, which are typical text forms in the field of STEM, it is essential that the reader pays attention to the text structure features. In turn, the reader has to evaluate the relevancy of information in relation to the task which is to be accomplished, to the problem which is to be solved, or to the product that is to be designed (Dreher, 2002). In this context – when focusing on text understanding on higher cognitive levels – general functional literacy overlaps with specific scientific literacies, among them with STEM literacies, and, in their framework, with science, technological and engineering literacy. The term *technological and engineering literacy* refers to, apart from an ethical use of scientific and engineering knowledge, also to the knowledge about science, technology and engineering and the competence of understanding and using science/technology/engineering knowledge as the applicative part of science. The competence of communicating about the scientific, technological and engineering topics is an essential part of STEM literacy. In this sense of the word, technology and engineering literacy is an integral part of STEM literacy.

Functional literacy in the field of STE, (and by way of analogy in other fields) should be understood (Aberšek, 2018; Dolenc, Aberšek, & Kordigel Aberšek, 2015) as:

– *information literacy in the field of STE* (finding and managing information, critically evaluating information, and being competent in using information in order to solve a problem);
– *functional literacy in the field of STE,* which means
– reading expository and/or explanatory texts from the field of STE, understanding such texts (in verbal and visual code), and using the knowledge acquired this way to solve problems;
– reading/writing certain text types, such as *description of a procedure*, *instructions for use*, *building/manufacturing instructions*, etc., understanding such texts and using what was read to successfully and safely use a new product, make a product, assemble furniture, and so on.

Research Methodology

In the first step, a metacognitive model for science, technology and engineering literacy (McM_T&E) was developed. After developing the McM_T&E model, an evaluation was necessary. The basic research and evaluation method applied in the present study was an experimental method of pedagogical research. The methods used to belong to the framework of quantitative and qualitative research. In the preparation and adaptation of the metacognitive model (McM_T&E), action research was used to collect data on how the lessons and schoolwork were conducted. Basic information about the students were obtained with a questionnaire and a non-experimental method. Students' knowledge and the efficiency of their work were tested quantitatively, by measuring reading time and reading understanding of an *expository text* from the field of engineering and technology and an example of *manufacturing instructions,* and qualitatively, by evaluating the quality of the manufactured product according to *manufacturing instructions* and according to the creativity of the solution (Cencelj, Kordigel Aberšek, Aberšek, & Flogie, 2019).

Research Procedure

After discussing and coordinating with teachers of the school subject Slovene language and literature, students learned about different reading strategies and were introduced to a variety of examples about how to use these strategies in their mother tongue class. Next, a test was carried out to identify the existing situation – the ability of transferring the general functional literacy, acquired in the mother-tongue classes, to the level of functional literacy in the field of engineering and technology. Reading speed and text understanding were tested in two reading situations: reading an expository text from the field of engineering and technology, and reading manufacturing instructions from the field of engineering and technology (Cencelj, Kordigel Aberšek, Aberšek, & Flogie, 2019).

The next step was the adoption of learning content about the materials needed in the working process, and the production of the product. Students were divided into two groups: the experimental group (EG) and the control group (CG). Students in the CG were taught using the traditional teaching method. Students in the EG were taught using the new, metacognitive model for developing *technology and engineering* functional literacy (McM_T&E), which is based on process-oriented instruction, focuses on developing functional literacy in the field of engineering and technology, and uses formative monitoring of the student's progress.

In the last phase, the reading comprehension of an expository text from the field of technology and engineering and of manufacturing instructions, was re-tested. By comparing the obtained results, the students' progress in reading speed and in understanding of the read text, was measured. In both examinations (both in the pre-test and at the end of the survey), the same text was used, and both groups were given the same criteria for evaluating work and the same content treatment, which in the end produced comparable results.

Sample

The research was carried out in classes of ‘Technology and Technique’ (TIT classes), as part of a thematic area called ‘making products from paper materials’. The survey included 108 students from a smaller town school, settled in a peripheral region of Slovenia, who attended the six and seventh grades at the same primary school in the school year 2017/2018. Out of these, 68 were students of three divisions of the sixth grade (63%) and 40 were students of two divisions of the seventh grade (37%). The sample was collected from all sixth and seventh grade classes at this school. According to gender, the sample consisted of 55 boys (51%) and 53 girls (49%).

Data Analysis

Microsoft Excel 2016 was used to organize the obtained data. For statistical processing of the organized data, the SPSS 22.00 software package was used. Data was processed and presented at the level of descriptive and inferential statistics. At the level of descriptive statistics, frequency distributions (f, f %), mean value measures, variation measures, correlation measures and the Kolmogorov-Smirnov test for testing normality, were used. Some of the ordinal variables (multilevel scales) were considered as interval, with the assumption that the differences between the values were the same. This way of dealing with variables referred only to the calculation process, and not to the interpretation of the results obtained.

Research Results

Regarding the analysis of text comprehension, the study presents the results of reading comprehension, with regard to expository texts from the field of engineering and technology and manufacturing instructions for the EG: before and after the implementation of the metacognitive model for developing *technology and engineering* functional literacy (McM_T&E).

The expository text comprehension results show that only 3.7% of the students have achieved results which classify them as 'bad readers' (18.5% of students in the pre-test), and 18.5% of the students have achieved the results which classify them as 'slow readers' (53.7% of students in the pre-test). The number of science and engineering functionally literate students grew remarkably, viz.: 14.8% in the pre-test, and 53.7% in the post-test. These are students, who reached the level of 60% to 75% of correct answers. Also, the number of students who reached the highest level of reading comprehension grew: from 13.00% in the pre-test to 24.1% according to the post-test.

The results of reading comprehension in the CG classify 31.5% of the students as 'bad readers'. These students have all made progress – in the post-test, there were no bad readers in this group. The results for average readers show a different picture: the group of average readers hardly changed (44.4% in the pre-test, and 46.3% in the post-test). The number of functionally literate students in the field of engineering and technology grew: 14.80% in the pre-test, in comparison to 51.9% in the post-test. The number of very good readers grew: 9.3% were classified as 'very good readers' in the pre-test, and 24.1% in the post-test. The results concerning the reading comprehension of manufacturing instructions draw a similar picture and confirm the effectiveness of the metacognitive model for developing *technology and engineering* functional literacy (McM_T&E).

Conclusions

Functional literacies in individual subject areas can only be the result of cross-curricular co-operation between a mother-tongue teacher and a subject teacher, or teachers, with the share of responsibility leaning towards the latter as the level of education progresses. It needs to be clear, of course, that only properly qualified teachers will be able to competently perform their role in this process. Therefore, they need to be trained in at least two areas, namely, in the field of functional literacy, in particular STE functional literacy, and in collaborative work. If this is to be achieved, methods of working with teachers must change, and in turn, teachers must also adapt their ways of working with students and begin applying different teaching and learning methods, such as the proposed metacognitive model McM_T&E for training students in science, technology and engineering literacy.

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ONE CHEMISTRY - TWO MEANINGS. SCIENCE AND EDUCATION: COMPARATIVE ANALYSIS OF THE ROLES, PRESENTATION AND APPLICATIONS

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Abstract

The comparative analysis of different meanings of Chemistry is carried out, taking in account philosophical, didactic, psychological and socio-cultural aspects. The issue is discussed in terms of the concurrent existence of two different subsystems referred both to Science and Education which can be found in presentations of chemistry knowledge. The study overviews researcher's findings made in the field of Science Philosophy and Chemistry Didactics. Theoretical study based on profound concepts from Science and Chemistry philosophy as well on few empiric researches carried out by researcher in the field of Chemistry Didactics.
Keywords: *beautility, chemical object, chemistry education, modelling in science, visualization-based teaching*.

Introduction

What is Chemistry? Referred either to Craft, Art, Science or Philosophy? Why we need Chemistry? Only because we need products resulted from Chemistry activity? Or we could find from this activity something more: aesthetic and spiritual?

We live in the world where Technology and Science are among the forces defining the development of any country. Education gives people skills and knowledge, which make Technology and Science the tools to gain a progress and success. The time science created crisis seems to go away and just now the same science may resolve the most exciting challenges of our life. Chemistry is cornerstone of a scientific paradigm: it operates the body of exact sciences, explores the nature and concerning many humanitarian and social issues. Thus, questions how to explore (Science) and teach (Education) chemistry in all the aspects and what ways to choose for organizing a process of research and education are of great importance both for fundamental or applied researches and social, cultural and economic development of any country.

The other problem is how to distinguish two different meanings of one field of knowledge (Chemistry particularly): Science and Education (here cutting more general meaning of education to academic discipline). The scheme reflects the simplified interconnection between these divergent, but interdependent categories based on general basic invariant (object) and variable subject units, the latter having its own ramified system out of the focus of this analysis.

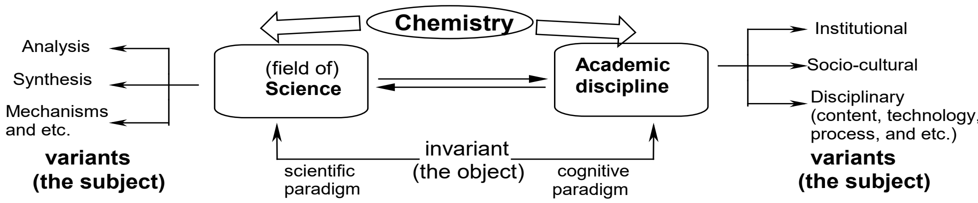

Figure 1. Interconnection between scientific and educational paradigms of Chemistry.

Research Methodology

The purpose of the study was to review previous findings in the field of Science Philosophy and Chemistry Didactics. Theoretical study based on profound concepts from Science and Chemistry philosophy as well on a few empiric researches carried out by the author in the field of Chemistry Didactics. Comparative analysis of the role, presentation and application of Chemistry knowledge was done based on the author's original articles devoted to theoretical principles of chemical philosophy and empiric researches in the field of Didactic Chemistry.

Population in empiric researches mentioned in the article included few groups of respondents. It covered almost all the ages starting from primary school pupils (Lakhvich, 2008) up to University students, and different lines of education. In all experiments two groups (experimental and control) were formed based on the results of pre-intervention test. The main reason of the sampling generalization was to form the bigger groups to validate the microstatistics under the circumstances of respondent lack. Pre-intervention test showed the statistical uniformity of both groups consisting of students from different age groups.

Visualization-based teaching has been implemented. The latter included models, animations, experiment, play-therapy, molecular docking and etc. Animations assisted different topics and the emphasis was made to form a visual-based acceptance of chemistry information, regarding the attractiveness and age-related accessibility of the models. In control groups students were supplied with regular didactic materials and accustomed educational techniques.

Research Results

In the beginning it is possible to start with a few attempts to understand the terms and find the common denominator for the two meanings of Chemistry knowledge.

Chemical Objects as Integration Unit for Chemistry

Roles, applications and presentations are variable. The objects integrate both paradigms in one branch of knowledge. Taking into account all previous empiric findings and modeling about the structure of matter it's worthy to discuss three types of chemical objects: substance, molecule, and finally chemical presentations (or chemical models)

(Shummer, 1998; 2003). The latter category can't be neglected, because in most cases in educational process and in many cases in science we operate with presentations. Chemical formulas are the simplest example of chemical presentation that is quite different both from substance (possessing physical and chemical properties) and molecules (characterized with shapes, stereometry, distances between atoms, etc.). Formerly, we discussed the applicability of different formulas both in Education and Science (Lakhvich, 2006, 2007, 2010). They are neither substances nor molecules, integrating meanings from both. Inexperienced scholar could suppose the structural formula would be a simple pictogram reflecting geometry of the molecule. But obviously, the chemical bonds presented as lines (solid, dashed and wedged) barely reflect the real distances between atoms, mostly presenting the arrangement of atoms in space and strengthening the idea about prevalence off attraction on repulsion in chemical compound. The latter originates from molecule meaning. Chemical bonds in structural formula originate from substance meaning reflecting mostly the ability to take part in chemical reactions. The model of double bond is the great evidence for this. Obviously, it visualizes the chemical property of the substances to be saturated (the fact found in the experiment), the latter gave rise to double bond presentation model to visualize the substance "saturation" in terms of addition process. Instead of double bond we obtain two new bonds, and thus introduction of new atoms in compound being visualized in an adequate model.

Modeling and Visualization

Adequate modeling is a key technique for presentation of chemical objects both in science and education. The initial period of Science itself and Science Education was based on the experiment. The new Science paradigm is rather formal by nature and fundamental in Philosophy meaning. Still the tool for interconversion between the empiric and theoretical moieties seems can be associated with the problem of modelling, which is one of the most important in modern Science. Formerly, we postulated (Lakhvich, Kostareva, & Lehankova, 2009; Lakhvich, 2010) that adequate modelling and visualization in particular is to be the core element for the modern Educational model and paradigm for Science. A great number of publications, devoting to the problem, confirm dramatically its relevance. Still models were discussed in terms of object recognition and computational modeling. We consider the category of modelling is more comprehensive and can be discussed in various aspects, some of them are all-pervading philosophy principle (Harnad, 1987), psychological tool for cognition (Lakhvich, Kostareva, & Lehankova, 2009) and finally the model having for Science its own complex structure.

Models are appropriate not only for theoretical considerations but useful for practically oriented fields of Science. The typology of models has been developed regarding their hierarchy in dependence of their relative similarity (Trindle, 1984; Tomasi, 1986). Still it has been found (Tomasi, 1999) that for theoretical investigation the models can be classified in another way. The components of this subsystem are hierarchically dependent, and the most comprehensive definition refers to interpretative model. The interpretative model is absolutely appropriate for speculation of different scientific concepts; the adequacy of such a model ought to be judged with the aid of few criteria (generality, utility, self-constituency and etc.).

Structural formula is a good example of modeling of chemical objects and is widely used both in Education and Science. Molecular docking is another example of effective modeling. It predicts the preferred orientation of one molecule relative to another at their bonding to form a stable complex. Knowledge of the preferred orientation allows to forecast the strength of the association, or affinity to binding between two molecules. This modelling is widely used in Molecular Biology, Computational Chemistry and Drug Design (Scientific paradigm) and can be effectively introduced in Educational process (Educational paradigm).

Science Modeling vs Educational Application

Molecular docking has been developed actively for about three decades (Lengauer & Rarey, 1996; Kitchen, Decornez, Furr, & Bajorath, 2004). My own experience when working with Pharmacy students has demonstrated the relevance of the approach in educational process, in particular in context of introduction of inquiry technology which is aimed on using and learning content as a means to develop information-processing and problem-solving skills. Such approach is student centered, them being the participants of the projects.

Though inquiry can be done even in lectures, the best results are distinguished in lab or group work, and in particular within carrying out the student research. There are a lot of investigations done about the Student Research, including both fundamental works (Peters, 2012; Strayhorn, 2013) and focused on definite fields of knowledge, e.g. few investigations in the field of Biomedical and natural Sciences (Amgad, 2015; Ballamingie, 2013; Slack, 2016).

Student Research (SR) is often wrongly associated with lab studies. However, on the one hand, not every lab experiment is a study, on the other - similar to originally scientific research, SR is based on the same procedure and includes formulation of research problem, work with literature, design of experiments (formulating of the aim, conceptual framework and specific questions of research, choice of methodology and procedure), conducting the experiment itself, data collection followed by their verifying, analyzing and interpreting, summarizing and finally presenting the results (publishing and conference activity). Most of universities provide the equipment and resources for real scientific research, which is problematic for high and secondary school. But in all cases students are limited in time, being involved in different forms of academic activity. This makes the idea of the “real scientific research” illusive for most of students. To resolve the problem, an educator must organize SR in such a way to take in account all procedural, psychological and didactic aspects of educational process (Lakhvich, 2017):

- to use only few elements of research technology: the higher level of education, the closest research structure to scientific research;
- the experiments do not necessarily have to be absolutely innovative; the key point is a subjective novelty of the research for the students;
- the research primarily pursues educational and training rather than utilitarian objectives;
- mostly modeling, rather than useless transferring the real problem situation of scientific research in student research, with the exception of expensive equipment and materials;

- to take into account the psycho-physiological profile of students in particular age group.

We have proposed students (mostly from School of Pharmacy) the projects concerning primary investigation of bioactivity of organic substances as potential drugs. Molecular docking was the key element of the SR (Kitchen, 2004). SR included also the literary review and drug analysis (Journals, drug databases), the choice of the substrates (protein databases), the evaluation *in silico* the model, design of drug-candidates and the assessment of their activity *in silico*. The results obtained were valid and correlated with the data from previous researches, were presented in conferences and published. SR motivates students to study professionally oriented topics, trains their skill in the field of pharmaceutical chemistry and molecular biology, as well as helps us to find the candidates for entering the Master and PhD programs.

Aesthetics vs Applicability

Regarding the role of the Chemistry in scientific and educational context we should discuss its aesthetics and applicability. Formerly, we tried to apply the concept of Beautility to Chemistry meaning (Lakhvich, 2010).

Economics grab all the headlines, but beauty is just as important and even has serious financial ramifications. Beauty does serve a function. Beauty is more than skin deep. Beauty is powerful. Utility is beautiful and beauty has utility. Let's call it **'**Beautility**'** for short. Thus, beautility is a definition for objects that is both beautiful and useful, generally objects of special design (industrial, handmade, and finally in our case synthetic origin) which are meant to have utility while having a pleasing aesthetic. Like water and health care, Beautility is an essential civic utility that sustains our life form.

Earlier we postulated (Lakhvich, Kostareva, & Lehankova, 2009) a few additional criteria to judge models in a didactic framework. Models for the academic disciplines need to be adequate, effective, contemporary, exciting, and finally appropriate for successive usage. The similarity between real objects and models can almost be neglected in this context. To create an effective molecular model, we need to accept the influence of many features and conditions, which include both the nature of real objects and didactical (for the academic disciplines) aspects.

Postulating the model/visualisation is to be exciting, we strengthen the idea about aesthetic potential of chemistry knowledge. "Chemistry, the art, craft, business, and now science of substances and their transformations, is today paralleled at every step by hard-won microscopic knowledge of molecules and their reactions" (Hoffmann, 2003). Chemistry is also human labour, and/or matter of their activity. For those it gives both feeling of inspiration and sense of achievement as the feeling of spiritual gratification. Their products (both mental and tangible) originate perception of other people and thus granting the essence of what Chemistry induced. Aesthetics is commonly known as the study of sensory or sensory-emotional values, sometimes called judgments of sentiment and taste. It may be defined narrowly as the theory of beauty, or more broadly as that together with the philosophy and "critical reflection on art, culture and nature" (Encyclopedia of Aesthetics, 2003, p. 24). Aesthetics studies new ways of seeing and of perceiving the world. Thus, Aesthetics is cornerstone of a spiritual paradigm: it operates the body of fine arts and Philosophy, reflects the nature and concerning many humanitarian and social issues. References to Chemistry and Aesthetics reflect the symmetry and their interpenetration: scientific (empiric, objective and utilized) and sensual (spiritual, subjective and ephemeral), forming the symmetry of the World, and the latter looks very aesthetic.

Contribution: What We Have Done to Explore the Potential of Chemistry Visualization

We explored the problem of Chemistry modelling and visualization in different contexts. Based on the original concept (Lakhvich, 2009) of disciplinary didactic principles (DDC: structural adequacy principle, functionality principle, and mechanistic simplification) we elaborated the new didactic system for design of Organic Chemistry course. It consists of original epistemology, didactics, and mathematical evaluation of the adequacy of course design. Reactions were quantitatively assessed (Lakhvich & Vjunic, 2013) in context of their relevance to DDC. The latter includes formal division of reactions to simple stages, stage classification, and finally, matrix and graph analysis of reaction-stage database. Reactions are classified according to 4 criteria: Addition-Elimination, Nucleohilic-Elecrophilic, Carbon-Heteroatom associated processes, Single-multiple bonds. E.g. in acetal formation the hemiacetal protonation stage is classified as $\mathbf{A_{EH1}}$ process which means Electrofilic (**E**) Addition (**A**) to Heteroatom (**H**) with a single (**1**) bond. Based on graph theory and the approach (Tõldsepp, 2003) the continuity and compatibility of content units (stages of reactions) have been also assessed.

We also explored the effectiveness of different visualization and modelling techniques, in particular Condensed Visualization Technology (CVT). The empirical studies showed the utility of the didactic system proposed both for University and School students (Lakhvich, 2006; Lakhvich, Traunikava, & Efimava 2007; Lakhvich & Traunikava, 2009, Lakhvich, 2017). Within the experiments we judged the adequacy of CVT approach for Chemistry course design. That approach was indicated to be more effective for teaching Chemistry in didactic, methodological, cognitive aspects, particularly useful for short-period learning.

The special attention of our study was centred on the problem of the acceptability of CVT approach in general (grade 8-10) and pre-university (grade 11-12) school. On the basis of empiric data obtained (Lakhvich, Traunikava, & Efimava, 2007) we consider 8-10 grade school students are psychologically capable to perceive such level of formalization. The latter, to our mind, facilitates to the formation of so-called Chemistry type of mentality and force the possible reactivity of hit site of the molecule on students' attention.

Appealing results justified the acceptability of visualization type presentation of chemistry information for primary school (Lakhvich, Lehankova, & Traunikava, 2008; Lakhvich & Lehankova, 2009). Thus, we obtained 6-7- year pupils are able to resolve correctly problems in the field of Organic Chemistry, including tests on variety addition and substitution reactions (e.g. addition of methyl lithium to methylcyclohexanone) in the case we presented aesthetically and psychologically adopted technology. Grounded on the results we postulated the need of propaedeutic introduction of the chemistry language semantic subunits in primary school as the reflection of aesthetic potential of molecular representation. The main reason for such approach ought to be the realization of illustrative and imaginary thinking familiar to children of this age groups. The other reason was to facilitate the learning of Chemistry on the basis of the semantic system presented in propaedeutic introduction of molecular representation. Surely, the approach requires the adequate visualization techniques including excited samples (graphic and computer) and psychologically adaptive system of successive information presentation (CVT Technology).

The other contribution was made in the framework of the project aimed to facilitate the process of teaching hearing impaired students (Lakhvich, Kostarava, & Lehankova, 2009). The investigation included different forms of visualization-based educational techniques. The latter included various models, animations, chemistry experiment, play-therapy and etc.

Animations assisted different topics of general course and the emphasis was made to form a visual-based acceptance of chemistry information, regarding the attractiveness and age-related accessibility of the models proposed. Thus, the concept of valency was visualized in form of 4-handed (for Carbon), 3-handed (for Nitrogen), 2-handed (for Oxygen) and finally 1-handed (for Hydrogen and Halogens) mannikins. They were allowed to form chemical bonds and structure taking into account their valence/hand-capacity. Discussing topics from organic chemistry the isomerism of organic compounds was visualized in the same manner, in addition various animals were proposed as the imaginary models of chemical elements. The initial introduction of visualized social and/or domestic patterns followed by the interchange of the latter for geometrical figures grouped in proper manner and finally to structural formulae. The special attention was made to use of condensed visualization technology elaborated earlier and accessed for regular pre-university and university students. The approach had been pursued in the framework of game-learning therapy. The latter included students cast, which played elements forming chemical bonds. The game enhanced the usage of additional sensors accessible for deaf students (visual, tactile and kinaesthetic). The positive motivation facilitated the study process. The study showed great motivation of HI students to carry out experiments in school laboratory. The latter obviously correlates with the fact that impairing hearing has little effect on the ability to work in the laboratory. Moreover, circumstances are favourable for such students to realise their potential in science. We used the potential of the chemical experiments both in individual and collective forms. The latter was supplemented with graphic presentations, 3D-animations, molecular modelling and play therapy activity. We consider the schematic type of presentation when being aesthetic and adequate should facilitate the teaching process regarding the psychological aspects of "commix"-type of mentality familiar to recent generation "commix".

Modelling as it was mentioned above was also applied in the construction of inquiry technology educations, in particular for SR-learning both at the University and High school (Lakhvich, 2017). To simulate the SR activity, we guided docking modeling projects of potential drugs. It was done mostly because of the cheap equipment we needed for student research and were inspired by the work of the colleague who studied some biochemical issues with the aid of molecular docking. In some cases, we used species synthesized and tested on TB activity previously. In other cases, *in silico* researches were based on the analysis of data about bioactivity of the different groups of substances (cardiac glycosides, capsaicinomimetics, thymidilate synthase inhibitors, terpenoids, and etc.) When organized properly, docking modelling gives really new knowledge. But only in the case we use the proper scientific approach. E.g. in the case of TB drug research, we based on the previous experimental data (some substances have been synthesized, and then biologically assayed in vitro), followed by the elaboration of the model of interaction (we needed to propose the protein fragment for simulation *in silico*). Then we compared the results of *in silico* computations and tests *ex vitro* (on TB strands) and then generated mentally the new structures with fragments of definite shape and orientation to bond more effectively with receptor. Just a normal scientific research based on proper scientific paradigm! Our experience has proved that modelling was attractive and interesting for students. They really were involved both in experiment (it was available and productive) and in the process of acquisition of knowledge. They found out a lot about the subject of their professional interest and shared their knowledge with mates.

Finally, we prepared textbooks and handbooks (Lakhvich & Traunikava, 2013; Lakhvich et al, 2010; Lakhvich et al, 2017; Ryneiskaya et al., 2018, and etc.) based on the technology and our understanding of what is to be aesthetic to facilitate teaching process.

Sometimes we hear from our colleagues working in the field of Science and Science Education about the uselessness of models and simulations. They propose only to train skills to teach some operations which will be used in future professionally. I dare say it's a college approach to prepare blue-collar workers for a primitive industry.

Conclusions

Chemistry can be regarded as cornerstone of two interfering paradigms: scientific and spiritual. Aesthetic analysis of Chemistry meaning includes the cultural image of chemistry as well as chemistry's contribution to the image of the world and the chemists' behaviour to arrange-explore-produce their labs, instruments, materials, texts, research objects and, finally results according to the aesthetic criteria. Visualization and modelling of chemical information, which are of major priority for chemists, who more than any other scientists communicate with each other through images and symbolic units, comprise a special issue for consideration.

Empiric results from our previous studies confirmed that the idea adequate and aesthetically designed visualization promote motivation to do Science as well as to teach/learn Chemistry. It facilitates the understanding/encoding of "encrypted Chemistry meaning". The aesthetic nature of Chemistry gives rise to its new paradigm promoting a new attitude to Chemistry knowledge. Applicability of Chemistry knowledge is tightly connected with its aesthetic nature which can be regarded as the main spiritual motif for the development of the technology. And otherwise aesthetically designed products, including Chemistry objects and Chemists' activity seems to be useful and pragmatically aimed to satisfy the expectation of modern people "cultural and humanitarian-tendency" appetites of our time. And the best way to find the way from chemistry objects to sensual perception of a man is to visualize aesthetically encrypted Chemistry information. It can be done both in Science and Education.

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PRIMARY SCHOOL FOURTH GRADE STUDENTS' ECOLOGICAL ATTITUDE DIAGNOSTICS

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Abstract

Ecological attitude education in primary school is both important and special. That way fundamental moral values of a young person are formed. Every day increasing ecological problems become much more diverse. It is important to develop a man able to perceive the current ecological situation and able to live in a harmonious interaction with nature. It is sought that ethical, aesthetical, psychological, juridical person's relationship with nature would become the criterion of culture. The formation of a positive relationship with the surrounding world, the environment remains a very significant element of education in a primary school.

It is hopeful that the attitudes with respect to nature formed at this ontogenesis stage will remain for the whole life. In this context, it is very important to appropriately diagnose the current attitude structure and on the basis of diagnostics correspondingly organise the education process. In April 2019 a pilot research was carried out, in which 127 primary school fourth class students took part.

It was stated that in the attitude structure of this age children, the aesthetic attitude was prevalent. The last according to the ranking was the ethical attitude. Correspondingly, in the second position was the cognitive, and in the third – the pragmatic one.

Keywords: *diagnostic research, ecological attitudes, pilot research, primary school.*

Introduction

Ecological education is an inseparable part of natural science education in all general education system. This is especially important in the primary school stage. One of the main aims of natural science education is the person's natural science literacy. One of this literacy components is the ecological attitudes. Seeking to develop students' ecological attitudes, International Nature Conservation school programme is carried out in Lithuania, which since 2004 has been coordinated by Lithuanian Green movement. The main aims of this programme are – to raise students' consciousness in nature conservation sphere, to educate unconsumerised attitude towards nature and to unite children and young people for the nature conservation activity. The researchers state that ecological education is one of the decision ways by which providing knowledge and information about human and nature relationship, it is sought to improve the country's environmental situation (Judson, 2010; Stevenson, Brody, Dillon, & Wals, 2013). On the other hand, ecological education comprises not only environmental knowledge transference, but also cognitive and emotional values, which encourage people to change their attitude to the environment and to foster an appropriate environmental behaviour (Pandey, 2007).

Attitudes are evaluative schemes which determine the disposition to positively and negatively react and evaluate concrete people, things, phenomena or situations (Legkauskas, 2008). The main attitude function is to help the individual to meaningfully orientate himself in his social environment. The attitudes develop depending on age, cognitive activity period, social experience. The attitudes are based on a value system. Personality values reveal themselves through these attitudes. The attitudes form in the socialisation process (Berns, 2007). Attitudes have different sources. 7-11-year-old children watching and interacting with the environment form the attitude to macrosystem: watch television, hear adult conversations, observe their behaviour. The attitudes of this age children develop when they follow attractive and honourable models. Beside the family, school and peers have a very big influence on the formation of attitudes. The children of this age still do not have much life experience; therefore, when environment or evaluative schemes change, the attitudes very often change as well.

Four main ecological attitude types are usually distinguished: a person perceives nature as a beauty object/source (aesthetical attitude), as cognition/knowledge acquisition object (cognitive attitude), as a safety/conservation object (ethical attitude) and as a benefit source (pragmatic attitude). The researchers claim that usually not one any type, but two attitude types prevail (Jasvin, 2000). Realising natural science education in a primary school, it is important to know how the students' attitudes are distributed. Thus, one can purposefully organise the education process itself. Therefore, the aim of this research was to ascertain the prevailing type of ecological attitude to nature, also to perform a preliminary methodological verification of the diagnostic instrument.

Research Methodology

General Background

The research was of a pilot type, carried out in the months March to April 2019. Research type was diagnostic. The research was grounded on a quantitative social research paradigm, holding the attitude that educational diagnostics allows evaluating rather accurately the analysed features. On the other hand, information derived from such research can be useful in developing educational practice. It is important to assist teachers to improve their teaching practice, because many teachers have difficulty in using assessment (diagnostic information) to improve their teaching (Sun & Suzuki, 2013). The researchers were holding an opinion that a pilot study is a small sized study which may be used before larger scale study of any type.

Research Sample

Fourth form students from 5 Lithuanian primary schools participated in the research. A convenience sampling which is one of non-probability sampling procedures was used. In the research, 127 students took part. Out of them 70 girls (55.1%) and 57 boys (44.9%). Before the research, a verbal respondents' agreement was received to carry out the tasks. Such sample is considered sufficiently representative for the pilot research (Viechtbauer, et al., 2015).

Research Instrument and Procedure

In the research, verbal association technique was used for personality ecological attitude identification (Jasvin, 2000). The measurement instrument was made of 12 blocks, each of them comprised stimulus word and five association words (see appendix). Four of the presented words corresponded to the concrete attitude type, the fifth word "rubbish" was for attention distraction. The respondents carried out the tasks in written form.

Original technique (Jasvin, 2000) was translated from Russian to Lithuanian and later to English. Two researchers individually carried out translation validity. Later certain concepts were discussed, and after the discussion with two experts some of them were changed (e.g., the concept "silage" /rus. „силос"/ was changed into the concept "fodder"; the concept "incisors" /rus. „резцы"/ was changed into the concept "teeth").

Data Analysis

For the obtained data analysis, the measures of descriptive statistics i.e. absolute and relative frequencies, standard deviation, mean were applied. In order to ascertain possible differences among variables, non-parametric Mann-Whitney criterion *U* was applied (comparing rank mean differences between the two groups of respondents).

Research Results

Having analysed the obtained data, the respondents' options spread into four main attitude types (Table 1).

Table 1. Respondent option distribution (N(%)).

Stimulus word	Attitude type			
	Aesthetic	Cognitive	Ethical	Pragmatic
FOREST	30 (23.6)	46 (36.2)	20 (15.7)	31 (24.4)
DEER	76 (59.8)	37 (29.1)	8 (6.3)	6 (4.7)
GRASS	60 (47.2)	31 (24.4)	25 (19.7)	11 (8.7)
LAKE	51 (40.2)	25 (19.7)	9 (7.1)	42 (33.1)
BEAR	21 (16.5)	6 (4.7)	7 (5.5)	93 (73.2)
TREE	35 (27.6)	47 (37.0)	20 (15.7)	25 (19.7)
SWAMP	30 (23.6)	38 (29.9)	20 (15.7)	39 (30.7)
DUCK	7 (5.5)	28 (22.0)	19 (15.0)	73 (57.5)
FISH	19 (15.0)	73 (57.5)	11 (8.7)	24 (18.9)
GARDEN	62 (48.8)	10 (7.9)	14 (11.0)	41 (32.3)
BEAVER	13 (10.2)	95 (74.8)	7 (5.5)	12 (9.4)
NATURE	79 (62.2)	22 (17.3)	10 (7.9)	16 (12.6)
Option sum	483	458	172	411
Mean	3.80	3.60	1.35	3.24
SD	1.65	1.59	1.46	1.52

Having evaluated option sums, one can see that aesthetical attitude got the strongest expression and the ethical - the weakest one. Cognitive attitude was in the second position. The attitude that had the weakest expression to nature objects and animals was ethical. It is obvious that the children of this age do not have much relationship with nature experience, therefore, inner moral norms are not settled.

Possible differences were analysed according to the respondents' gender using *U* criterion. The obtained results are presented in Table 2.

Table 2. The respondent attitude differences according to gender.

Attitude type	Gender	*N*	**Mean Rank**	**Sum of Ranks**	*U*	*p*
Aesthetics	Girl	70	68.28	4779.50	1695.500	.139
	Boy	57	58.75	3348.50		
Cognitivism	Girl	70	67.30	4711.00	1764.000	.252
	Boy	57	59.95	3417.00		
Ethics	Girl	70	57.39	4017.00	1532.000	.020
	Boy	57	72.12	4111.00		
Pragmatics	Girl	70	62.98	4408.50	1923.500	.724
	Boy	57	65.25	3719.50		

It can be seen from the table that only in one case the respondents' attitude type statistically significantly differed. The boys' ethical attitude rank (72.12) was statistically significantly higher than the girls' rank (57.39). One can claim that ethical attitude is more characteristic of boys: respect to nature, care, safety and so on. Though statistically significant difference was not fixed, however for the girls (68.28) more than for boys (58.75) were characteristic aesthetical attitudes to nature objects and animals. A hypothetical assumption can be made that boys follow behaviour rules, norms and requirements more in the relationship with nature and in the girls' relationship with nature aesthetical attitudes are prevalent.

Conclusions and Implications

Research results allow asserting that the strongest expressed attitude to nature objects and animals of the fourth form students was aesthetical, and the ethical attitude got the weakest expression. Cognitive attitude was in the second position, and the pragmatic – in the third one.

Research results revealed that ethical attitudes to nature objects and animals are more characteristic of boys than girls.

With regard to education process in primary school, it is necessary to form positive attitudes of the children to nature. Various sources: books, television, communication with the adults and other can help form positive attitudes about nature. Direct experience and one's own behaviour observation can particularly form the attitudes. Therefore, it is necessary to form conditions for the children to more often practically cognise nature, listen to interesting narratives about nature, to help them understand nature importance to man. Children tend to listen more to those attitudes, which are constantly spoken about, publicly declared. Attitudes which are acquired from your personal experience have a bigger influence on behaviour /conduct in general.

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Appendix

Verbal association technique

Example: word BALL: red; football; big; rubber; children's. As an answer you can mark e.g., the word "rubber". You should answer quickly, because your first reaction will reflect your option best.

So, we can start!

FOREST	Clearing (A)	Anthill (C)	Reserve (E)	Firewood (P)	Sand
DEER	Traces (C)	Forester (E)	Trophy (P)	Stones	Antlers (A)
GRASS	Watering (E)	Fodder (P)	Bark	Dew (A)	Stem (C)
LAKE	Treat (P)	Wool	Islands (A)	Mollusc (C)	Cleaning (E)
BEAR	Cobweb	Master (A)	Raspberries (C)	Rare (E)	Fur (P)
TREE	Autumn (A)	Tree rings (C)	Growing (E)	Furniture (P)	Hay
SWAMP	Tadpole (C)	Reserve (E)	Peat (P)	Apples	Fog (A)
DUCK	Prohibition (E)	Steak (P)	Dawn (A)	Branch	Ringing (C)
FISH	Gills (C)	Silver (A)	Spawn (E)	Frying (P)	Feather
GARDEN	Den	Blooming (A)	Pollination (C)	Care (E)	Harvest (P)
BEAVER	Swiftness (A)	Teeth (C)	Settling (E)	Fur coat (P)	Mushrooms
NATURE	Beauty (A)	Cognition (C)	Safety (E)	Use (P)	-

Note: A – aesthetic attitude, C – cognitive attitude, E – ethical attitude, P – pragmatic attitude.

STUDENTS' NATURAL SCIENCE CONTEST: TASK ANALYSIS IN THE ASPECT OF KNOWLEDGE AND UNDERSTANDING

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Abstract

National contest "Lithuanian naturalist" 1st -2nd form students' team (15) performed task (from animate nature and people's living environment sphere) analysis was carried out. The attention was paid to students' natural science knowledge and understanding.
The research was grounded on the attitude that this contest as a non-formal education form is an effective device because it contributes to natural science education quality in primary school: 1) develops primary school students' natural science literacy; 2) makes possibilities for teachers to reflect on their experience and proposes ideas for the education process improvement; 3) for students – future primary school teachers – provides a possibility to acquire new experience (task creation, conducting theoretical and practical parts of the contest, preparation of evaluation instructions, students' work evaluation).
Keywords: *natural science knowledge, natural science contest, primary school students, pre-service teachers*.

Introduction

In the society considerations can be heard if students' participation in contests is *good* or *bad*, in which students are inevitably accompanied by competition and negative emotions. Discussing this question, one should search and find more positivity. Students' contest organisation is useful due to many things: teamwork skills are improving, inner motivation is increasing, academic achievements are stimulated. Neubert (2016) also mentions: Enhancing Social and Emotional Learning, Building Mental Toughness, Improving Risk Analysis and other. In addition, the contest "Lithuanian naturalist" helps to better cognise the nearest natural environment, improves natural environment research skills, develops environmental attitudes. The contest is carried out by Lithuanian students' non formal education centre, its partner – Vilnius university. Childhood study programme (Primary education pedagogy) 2nd course students, taking part in this event, improve many pedagogical and subject competencies.

Speaking about knowledge and understanding in primary education, concepts play the most important role, which in future will form the foundation making laws, theories and ideas, and this means that the acquired scientific concept system will be the basis learning in senior forms. In psychology the concepts are divided into scientific and non-scientific (domestic, pre-scientific) (Gučas, 1986). According to Vygotskij (2000), natural science knowledge acquisition first of all is related to the fact, term and concept learning. Cognitive concepts, according to the author, include assumptions, explanations and grounded assertions about natural science phenomena and processes.

The main knowledge acquisition peculiarity is the fact that the acquired knowledge is long term and stable. It is very important how students are able to reflect on it according to certain features. 7 to 9- year old child learns to logically and abstractly think and understands that certain features can differ one from another, and this means that he is able to discern them and to name:

- certain essential object features called a group of features, each of which separately is necessary for an object, and all of them are sufficient that owing to them a certain object could be separated from the adjacent objects;
- non-essential object features, considered such features, which an object can have or cannot have, however, not having them, an object remains the same as it was;
- general features, which are common to all particular concept objects. Any object group namely forms a concept because particular general features are common to all of them (Plečkaitis, 2004).

Contest theoretical tasks were prepared taking this into consideration. Though a contest is not only check-up of knowledge and understanding. In the practical part which takes place in the laboratory or in the natural environment, students' abilities are checked: to research, group, classify, contrast and compare, analyse, recognise and so on. Except the competitive part, the participants have also entertainment: peers give concert to them, education takes place. Therefore, the participants have a possibility to get acquainted, share, find out, experience something new. Children having completed the tasks and evaluation board having evaluated them, all participants are presented remembrance gifts, participant's certificates, and those who collected most points receive diplomas. Teachers are presented with the former tasks, students typical mistakes are discussed, it is advised how to teach one or another natural science subject. This part is rather important for the teachers, because it is a possibility to reflect on one's work practice and generate new ideas.

Research aim was – to analyse 1st -2nd form student, having participated in the republican contest "Lithuanian naturalist" carried out theoretical part tasks, and after evaluation of students' knowledge and understanding give recommendations to primary school teachers.

Research Methodology

Research Characteristics

The research was carried out in May 2019. This is a republican contest "Lithuanian naturalist" 2nd - round theoretical part students' performed task analysis. The performed theoretical tasks at this stage are oriented into "World cognition", integrating social and natural science content, the following spheres: animate nature and people's living environment.

The research is grounded on the attitude that various non formal education forms including a republican contest "Lithuanian naturalist" is an effective device developing students' natural science literacy and seeking natural science quality in primary school.

Research Sample

In the research participated 30 1st -2nd form students (8-9 years old), from 15 different Lithuanian schools. These are 15 teams (two students in each), having expressed willingness to participate in the republican contest "Lithuanian naturalist"

Instrument

A questionnaire was used for the research (activity sheets), which comprised 4 tasks: 1) animal cognition; 2) Lithuanian map and the weather; 3) the plant needs; 4) parts of the plant. For the result evaluation, evaluation instructions were prepared.

Research Results

The first theoretical task was devoted to animal cognition. 10 animals were chosen belonging to different animal groups: insects, molluscs, amphibia, reptiles, birds and mammals. Demonstrating these animal photos on the screen, the teams had to name the presented animal and to do one task each, related to this animal. How 15 students' team succeeded in cognising animals is depicted in Figure 1.

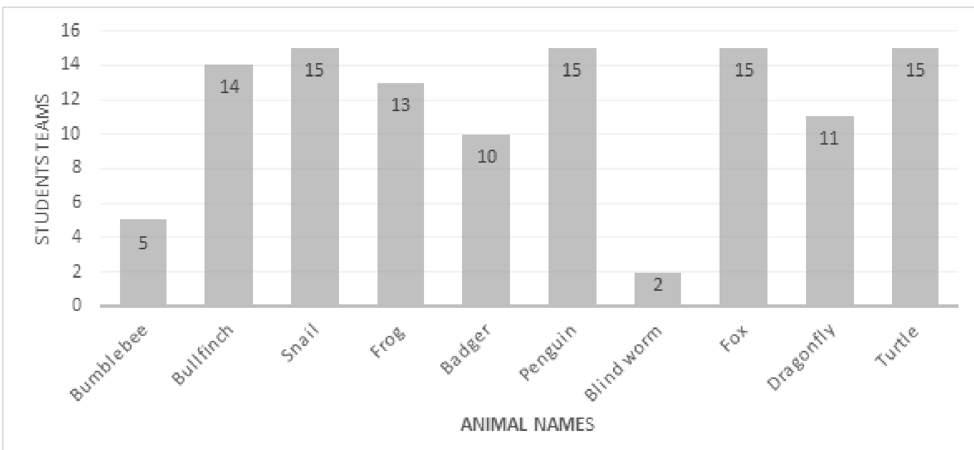

Figure 1. The team number, having correctly named the presented animal names.

Only one third of the teams recognised *a bumble bee*. Students usually confused it with a *bee, hornet*, *wasp*. The task required to *name at least one related animal to it [bumble bee]*. More than half of the participants pointed out *a bee.* The remaining part selected the other Hymenoptera group insects: *hornet, wasp.* Thus, presenting related animals the contest participants were not mistaken, they indicated Hymenoptera group representatives.

Even14 teams properly named the second animal – *a bullfinch.* And even though no one indicated animal species, however, the family was named correctly, because they knew the feature – the abdominal side of the body was brightly red. It was asked to *indicate what the body of this animal was covered by.* All the teams indicated correctly– *by feathers.* Thus, the students know this characteristic feature of the bird class.

All the teams recognised *a snail*. It was asked *to name an animal part shown by an indicator* (an indicator marked a shell). All the teams pointed out correctly. One of them wrote more precisely *shell or cockle shell,* and the other: *shell – little house.* This shows the relationship still existing between scientific and domestic concepts, though they related the feature to an animal without any problems.

Most of the participants cognised – a *frog* – the fourth animal. A few teams were convinced that it was *a toad*. Students were asked *to contemplate what relates this animal to a tadpole* Two thirds of the teams contemplated like this: *tadpoles are frogs' children; it is related to a tadpole, that it is a frog's child; both are frogs; tadpoles are small frogs; tadpole is a growing frog; from a tadpole develops a frog*. However, as can be seen, three last answers are more scientific. Besides, speaking about animals, the concept young should be used, but not a child. On the other hand, the concept young is used when we talk about birds and mammals. However, as one can see, the respondents still do not pay attention to this. The third of the teams did not demonstrate deeper natural science knowledge. According to them, a frog to a tadpole relate: *eyes; the same appearance of the head* or *water* and that *both of them swim.*

Two thirds of the teams recognised *a badger*. It was asked to tell how this animal *spends the winter*. Students teams contemplated correctly: *it sleeps all winter; it sleeps a winter sleep; accumulates fat and falls asleep; sleeps.* However, one pair of participants was wrong saying that in winter a badger *is walking.* The teams which named an animal wrongly (*ferret*, *raccoon, skunk)* still thought that it *during winter sleeps*.

The sixth presented animal was *a penguin*. All teams recognised it, two of them even indicated an animal species – *a royal penguin*. It was asked to tell, *where this animal lives*. One fourth of the teams were wrong indicating that these penguins lived in the north. This is a frequent primary school students' mistake: penguins' living place is associated with cold, which is supposed to be in the north; and Santa Claus also lives in the North where it is cold. Children's poems also add up to the wrong image formation, which children learn in preschool age and remember the lines about a penguin living in the north.

The other animal was *a blind worm –* a legless lizard was the most complicated for students. Only two teams recognised it. Anyway, both these teams were from the rural places! The others called this animal *a snake*, *a grass snake* and one team – *a worm*. The students were asked to express an opinion whether this animal was poisonous, to explain why they thought so. Having recognised a blind worm, the students wrote: *not poisonous, because it is from the lizard family, and lizards are not poisonous; it is not poisonous, because it is a lizard.* The teams which wrote that this animal was a grass snake held the opinion that *the animal was not poisonous*, that it did not have poison. And those who pointed out that it was a common adder – a venomous snake, claimed that *it had venom glands*; *its bite was dangerous and so on.* Thus, students had knowledge about the latter reptiles.

One more animal was a *fox cub,* which was properly named by all teams. It was asked not only to recognise an animal, but also *to describe in brief how this animal orientates in the environment*. It was hopeful that the students would enumerate all five senses helping to orientate in the environment: eyesight, hearing, smell, taste, touch. About half of the teams pointed out eyesight, a little less smell, hearing. None of the teams thought about touch, though in the photo one can see tactile hair very well. The content of this question is scholastic therefore, it is hard to believe that students could not apply knowledge in the new context. Some of the students' answers went beyond logic. E.g. *a fox has a magnetic particle in its head; orientates according to the trees; a tail helps to orientate*. Two more answers have nothing in common with the question. E.g., *a fox eats smaller than itself; hunts.* An obvious problem is with the text /image perception.

A lot of teams correctly named a *dragonfly.* The other teams were not precise: *an insect; yellow-legged dragonfly* or were mistaken*: a glow worm.* One students' pair did not name this animal. The contest participants were asked to name *how many legs insects have.* The same part of the researched students' pairs correctly indicated that *insects have 6 legs* or *3 pairs of legs*. Four students' teams were wrong claiming that *insects have 4 legs* (anyway, in the illustration one could see only 4 legs). Thus, a part of respondents still lacked elementary knowledge about this animal group, because they did not name the main feature.

In the last photo was *a freshwater turtle* living in Lithuanian southern regions, recorded into the Red book. It was a wish that 8-9-year old children name at least the family– turtle. All the teams recognised a turtle. Moreover, it was a wish that students in a few sentences tell about *this animal conservation*. Because, this animal is endangered and conservationists, regional park workers carry out their accounting, raise them in the zoo and then let them into freedom. There were quite a lot of reports on TV, radio, press about conservation of these animals. However, none of these teams related this question to the turtle conservation, but wrote about how this animal was adjusted to survive: *has a shell; when somebody attacks it gets into a shell; has a shell, therefore, it hides in it; the shell is very strong, withstands even the shot from the gun.* Under such situation, the task organisers have to take up the responsibility: they had to clearer form the question or to present an entry.

The second given task for the students was – *Lithuanian map and weather* (Figure 2).

In the activity sheets, Lithuanian map was given with the indicated eight cities. The teams were asked to work with this map and to carry out some tasks: there was a wish to ascertain students' abilities to orient oneself on a map, to name the world countries and so on. Indicating a city*, which is the furthest to the south,* two thirds of the teams were not mistaken. Their answer was – *Alytus.* The remaining teams indicated the other cities.

It was asked, which state *was northern Lithuanian neighbour.* Only 9 teams indicated correctly: *Latvia.* In the other answers were Poland, also Russia even Estonia, with which Lithuania does not have common boundaries.

Figure 2. Lithuanian map, given in the task.

The question, *What city is in Lithuanian west,* correctly answered 9 teams: *Klaipėda.* The other, apparently, still hardly oriented themselves on a map, did not know world countries, therefore, in their answers random cities were indicated.

Only one third of the teams managed to indicate the directions of *the wind blowing from the east*. The rest of the teams were wrong indicating the west and the north wind blowing.

It was asked to describe the weather: In Siauliai – *raining*, In Panevėžys – *cloudy,* in Kaunas – *clear*. Only half of the teams using conventional signs properly described the weather in all indicated cities. The others correctly used two conventional signs. Most often the students were mistaken describing *clear* by a conventional sign. Their conventional sign was *cloudy with clear intervals.*

The third task was *Plant needs*. It was asked to indicate what was necessary for any plant to grow. All teams indicated that *water* was necessary for the plant. A big part of the participants (*N*-12) know that *soil* and *warmth* are necessary for the plant to grow. More than half of the teams (*N*-8) indicated that *sunshine* was necessary, a little less (*N*-6) remembered that the plant still needed *air.* One team separately named that *human care, fertilizers* were also necessary. This, certainly, is not important because a lot of plants grow unattended, and not fertilized. Materials, being in the soil are sufficient for them.

The fourth task was *Plant parts.* Poppy is described in the picture. One can see very well a blossom, leaves, a stem, a fruit in it. It was asked to show the poppy's parts. All 15 teams correctly showed leaves. More than a half (*N*-9) correctly showed the stem. The remaining part (N-6) called the stem *stalk,* i.e. used a domestic concept. Most of the teams (*N*-13) correctly named a blossom. The remaining part (*N*-2) called the blossom petals. And this is only a part of a blossom.

More than half of the (*N*-8) contest participants correctly named *fruit*. Quite a big part of the respondents (*N*-6) called fruit *a bud*, one – a *seed.* And this is an inability to read visual information, because the features remained unfixed.

Students' teams were asked what part of a plant was not depicted in the drawing. Everybody answered correctly: *root.* Another question: *what matures in the fruit – in a porous box?* More than half (N-8) of the participants indicated *seeds.* The others said *poppies mature in the fruit*. The answer was considered incorrect because the plant was called like this. It was the wish that the students name the concept. One of the teams wrote an unexpected answer – *grains.* This can at least illustrate the students' understanding about very small poppy seeds.

Conclusions

More than half of the students having participated in the contest have a sufficient amount of natural science knowledge corresponding to their age and are able to apply it in new contexts. However, the knowledge of a part of 1-2 form students still is not long term and stable, their used concepts are not always scientific. Though theoretical tasks were of a different size and students could check themselves in different situations, nevertheless it was noticed that part of the teams did not sufficiently go deep into the question, did not attentively read it, therefore, not understanding what they were asked for, gave not full answers, and did not earn points for the team.

Another important natural science knowledge and understanding peculiarity is – features. Students being able to cognise them and recognise, discern, name, practically did not make mistakes cognising animals, parts of the plant or answering questions about them.

A discussion having taken part after the contest with the students and with the teachers in some way is growing them. This is like the news being sent about the variety of tasks, other contexts, natural science content complexity. Together an attention has been drawn to the World cognition subject drawbacks, that in future children do not come in touch with the more serious difficulties. Teachers were recommended to give more natural science lessons for primary school students not in class, but in natural education environments. If students grow plants themselves, take care of them, they will not only know their parts better, but also will use scientific concepts, will know and understand the plant's needs. Besides, they would experience the cognition joy, would better understand human and environment interaction problems.

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TEACHERS' ATTITUDES TOWARDS UNETHICAL USE OF MOBILE TECHNOLOGIES IN HIGHER EDUCATION

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Abstract

The purpose of research is to explore the attitudes of university teachers towards the use of mobile technologies and to explore their perception of the ethical aspects related to the integration of new technologies. There was applied a questionnaire with closed-ended and open-ended questions. The results of this research highlight university teachers' positive attitudes towards the use of mobile technologies in higher education. These technologies become pedagogical tools in higher education with multiple valences on teacher professional learning.
Keywords: *ethical aspects, mobile learning, university teachers*.

Introduction

In the last twenty years the use of mobile technology (MT) has exploded, which led to a very strong subject of research for the academic world. Many researchers have focused efforts to study the impact of cell phones, smartphones, and tablets on educational processes at various educational levels. El-Hussein and Cronje (2010, p. 20) defined mobile learning as "any type of learning that takes place in learning environments and spaces that takes account of the mobility of technology, mobility of learners and mobility of learning". Statistics Survey (2018) argues that the mobile phone penetration is forecasted to continue to grow, rounding up to 67 percent by 2019. Despite this, there is a gap between the use of Mobile Technology at the private and professional levels. Gartner Personal Technologies Study (2014) shows that mobile device adoption in the workplace is not yet mature.

Attitudes and Ethical Use of Mobile Technology

Previous studies have shown that although university teachers have been encouraged to implement information and communication technologies in daily activities, their attitudes about adopting new technologies are diverse (Kennedy et al., 2008; Gilroy, 2004). Some research shows arguments about resistance, scepticism and suboptimal utilization of MT (Blin & Munro, 2008; Dreher et al., 2011; Kirkup & Kirkwood, 2005; Pollara, 2011; Selwyn, 2007). If they are offered the opportunity, teachers even support the banning of mobile phones from being used in university classrooms (Gilroy, 2004). The main reasons for this position are that teachers perceive mobile devices as social tools that can distract the students from educational tasks (Pollara, 2011). Other studies show evidence that teachers are already embracing this change (Bain & McNaught, 2006). Also, Al-Emran et al. (2016) achieved an exploratory study focused on the higher education students and educators from the perspective of potential acceptance of mobile devices in the educational environment. A conclusion of their study is that M-learning can be a promising pedagogical technology for higher education.

In Romania there are few pedagogical researches on the attitudes of teachers regarding mobile technologies. Strungă (2015) explored the relation between virtual learning communities in initial education process and the development of students' professional identity. Cojocnean (2016) investigated the attitudes of Romanian high school students towards learning vocabulary in second language acquisition with digital tools. In this study we intend to investigate the attitudes of higher education teachers towards the use of mobile technologies and to explore their perception of the ethical aspects of the integration of new technologies. In our research we have discussed both the use of mobile technology in support of students, and mobile learning for teacher professional learning.

The aim of research is the identification of the attitudes of university teachers towards the ethical aspects of the integration of mobile technologies in higher education. The research relies on several questions: a) What is the attitude of university professors towards the use of mobile technologies in educational activities?; b) Are there differences regarding teacher attitudes towards MT, also considering teacher gender and specialization?; c) What is the perception of teachers about the ethical issues raised by using MT? and d) What is the perception of teachers about the rules to be respected for the ethical use of new technologies?.

Research Methodology

There was designed a quantitative study to measure teachers' attitudes towards unethical use of mobile technologies in higher education. The method of data collection is the questionnaire, due to the advantage of providing quantitative data in a short time and by a large number of participants. The concept of attitude towards the use of mobile technologies by teachers was operationalized in ten components corresponding to the ten items: useful and effective tool in education, opportunities for communication and collaboration among teachers, finding many resources related to work, more active operation of the course material by students, providing feedback to students, developing teaching abilities, work management, preparing courses for students, facilitating communication between students and teachers, the flexibility of the teacher's educational role.

Sample

104 university teachers from five Romanian universities participated in the study. Depending on the independent variables, the lot is divided into different categories according to: gender (83 female and 21 male); specialization (52 with the specialization of Mathematics and 52 with the specialization of Pedagogy).

Data analysis

All statistical analyses were conducted using the SPSS version 21.0 for Windows (IBM SPSS Statistics). Descriptive statistics have been used to measure teachers' attitudes towards the 10 aspects of using mobile technologies in education. Following the One-Sample Kolmogorov-Smirnov Test, one finds that the distribution is not normal, as Asymp. Sig. (2-tailed) < .05. The Mann-Whitney *U* nonparametric test was performed for measuring the difference between participants referring to the attitude towards the use of mobile technologies.

Research Results

Statistical averages indicate that the university professors have positive attitudes towards the use of mobile technologies in educational activities. In relation to gender, the values of the Mann-Whitney *U* test show that there are statistically significant gender differences at the level of the attitudes of teachers on nine aspects of the use of mobile technologies in education. Regarding specialization, the values of the Mann-Whitney *U* test (Table 4) indicate that there are significant differences in all aspects that concern teachers' attitudes toward using mobile technologies in education.

Based on the analysis of the frequency of teachers' answers to the *ethical issues* that determine the use of MT in education, it has emerged that the most frequent problems are as follows (Table 6): piracy of some software (n=32), inequality in student access to mobile technologies (n=22), retrieving information without reference to sources (n=21) and plagiarism (n=20).

Conclusions and Implications

The results of this research are useful for knowing teachers' attitudes towards the use of mobile technologies in teaching and learning activities in universities, as well as for raising the awareness of the ethical aspects of their integration into education. Identifying teachers' attitudes determines the knowledge of the situation about the acceptability of these technologies in the academic environment. The main rules of the ethical use of mobile technologies in education indicated by university teachers are: correct indication of the sources of information, the use of educational sites only during teaching, respect for copyright, setting a strict time to use mobile technologies during classes and developing an ethics code on the use of mobile technologies in education. Determining teachers' attitudes of the ethical aspects of using mobile technology highlights the awareness of the positive and negative effects of their integration into the educational process in higher education.

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MEASURING ATTITUDES OF BIOLOGY TEACHERS TOWARDS INTERNET

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Abstract

The main aim of the research was to identify the attitude of pre-service and in-service Biology teachers towards the use of the Internet. In this research, the Internet Attitude Scale has been applied, a validated and standardized instrument. The scale was applied to 210 Biology teachers, of whom 155 are pre-service teachers and 55 are in-service teachers in secondary and high schools from Romanian education. The research results indicated the existence of positive attitudes of pre-service and in-service Biology teachers to the educational use of the Internet.
Keywords: *biology teachers, internet attitude scale, teacher education.*

Introduction

There are a number of specific studies based on the exploration of pre-service biology teachers' attitude towards information and communication technologies (ICT). A part of these studies mainly examine pre-service teachers' attitudes towards ICT. Efe (2011) investigated science student teachers' intentions to use educational technology in instruction. Yapici and Hevedanli (2012) determined the pre-service biology teachers' attitudes towards information and communication technologies using in biology teaching. The results highlighted that pre-service biology teachers have manifested positive attitudes toward information and communication technology using in biology teaching. Aslan and Zhu (2015) identified pre-service science teachers' perceptions of ICT integration in teacher education. Kapici et al. (2015) examined the impact of technology-based learning on the attitudes of science pre-service teachers. Koksal et al. (2016) analyzed Turkish pre-service science teachers' perceptions on technology in terms of learning style, computer competency level, possession of a computer, and gender.

Unlike studies conducted on biology pre-service teachers, those aimed at exploring in-service teacher attitudes are more common. Dreyfus et al. (1998) identified the perceptions of actively engaged teachers regarding the advantages and problematics of using the electronic spreadsheet in biology teaching. Cavas et. al. (2010) explored Turkish primary science teachers' attitudes towards information and communication technologies in education and the relationship between teachers' attitudes and the factors related to teachers' personal characteristics (gender, age, computer ownership at home, and computer experience). Mansour (2010) investigated Egyptian science teachers' beliefs about teaching and learning science through Science Technology and Society education. Bettencourt et al. (2011) conducted semi-structured interviews with secondary biology teachers to identify their perceptions about Science-Technology-Society education. Muşlu Kaygisiz et al. (2011) measured the attitudes of biology teachers toward Computer Supported Teaching and the correlation between teachers' level of computer use and their attitudes. Gundy and Berger (2013) explored with the help of a qualitative methodology research the teachers' perceptions of integrating laptops into their biology courses in high school. Bitok (2014) identified Biology teachers' perception on the use of Information Communication Technology in teaching and learning activities from secondary schools. Fakomogbon et al. (2014) examined secondary school science teachers' perception of Information and Communication Technology for instruction based on their area of specialization. Osman (2014) evaluated the teachers' perceptions towards WebQuest, with reference to the technical, content and teaching and learning structure. Savaşci Açikalin (2014) analyzed teachers' perspectives regarding the use of instructional technologies in science classrooms. The results of study showed that none of the participants used internet, interactive smart boards, spreadsheets, computer simulations, and educational software in their lesson plans. Županec et al. (2014) investigated primary school teachers' attitudes toward Computer Assisted Learning in biology teaching.

The main aim of the research was to identify the attitude of pre-service and in-service Biology teachers towards the use of the Internet. The questions underlying this research were the following: a) What is the attitude of Biology teachers towards the Internet? and b) Are there significant differences between the attitude of the pre-service biology teachers towards the Internet and that of in-service teachers?

Research Methodology

General Background

There was designed a quantitative study to measure pre-service and in-service teachers' attitudes towards the Internet. The quantitative approach is appropriate for the objective study of human phenomena (Parahoo, 2014). The instrument of data collection was the questionnaire, which allows obtaining quantitative data and their analysis using statistical information programs.

Sample

The research group consisted of 210 Biology teachers, of which 155 are pre-service teachers and 55 are in-service teachers who teach in secondary and high school education in Romania. Pre-service teachers follow the training courses for the teaching staff at the psycho-pedagogical module within "Vasile Alecsandri" University of Bacău from Romania.

Data Analysis

Descriptive statistics have been conducted to analyze teachers' attitudes towards Internet. The distribution was not normal, as a result of applying the One-Sample Kolmogorov-Smirnov Test, which indicated that Asymp. Sig. (2-tailed) <.05. Therefore, Mann-Whitney *U* nonparametric test was used for measuring the difference between attitudes of pre-service and in-service teachers towards Internet. The SPSS version 21.0 for Windows (IBM SPSS Statistics) was used to perform all statistical analyzes.

Research Results

The results of the study were analyzed at a general level to highlight the attitude of Biology teachers towards Internet use and at a specific level to compare the attitudes of pre-service Biology teachers with those of in-service teachers. Analysis of overall results indicated a positive attitude of Biology teachers without using the Internet. Regarding the comparative analysis of the attitudes of pre-service biology teachers and in-service teachers to the Internet, there are no statistically significant differences.

Conclusions and Implications

Investigating the attitudes of pre-service and in-service biology teachers towards the Internet offers more opportunities for researchers and educators. First of all, measuring attitudes towards the internet indicates teachers' acceptance of technology as well as the extent to which they are willing to use them in biology teaching. Therefore, these studies contribute to knowing the possibility to exploit the new technologies by biology teachers in the teaching-learning activity. Secondly, the studies in the field of Internet attitudes are useful for improving pre-service teachers training programs from the perspective of preparing them for the use of technology in biology lessons.

The analysis of studies in this field has shown that research on in-service biology teachers is predominant in exploring their attitudes towards Information and Communication Technology. There are very few studies centred on determining the attitudes of biology teachers towards the Internet. It has also been found that there are few comparative studies of pre-service and in-service teacher attitudes towards new technologies.

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KNOWLEDGE-BASED APPROACH TO ADAPTIVE SELECTION OF EQUIPMENT FOR TEACHING ROBOTICS

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Abstract

Innovations and progress in teaching, introduction of new academic disciplines in the curricula, changes in the paradigm of school education in Ukraine, the search for innovative tools, techniques and teaching methods, especially teaching STEAM create a good basis for teaching robotics.
However, the organization of classes in robotics requires the creation of a special educational ecosystem, which important element is the technical base (equipment). It is not a secret, that administrative staff who sometimes even do not have required experience in technology are often engaged in the procurement of equipment and its selection. The current study was conducted to solve this problem, as well as to create a universal recommendation for creating an appropriate ecosystem for teaching robotics
As part of the study, the task was to develop a prototype of an expert decision-making system for selecting of an appropriate equipment and zoning of a classroom (ICR) for conducting classes in robotics. Knowledge-oriented approach was used to create the prototype.
Keywords: *knowledge-based approach, robotics, adaptive selection, teaching robotics*.

Introduction

The state of art in educational system development is associated with the expansion of interdisciplinary relations, integrated learning, the predominance of practice-oriented didactic tasks, and development of students' creativity. These directions are particularly relevant in the framework of the reforms being implemented in the Ukrainian educational system due to the "New Ukrainian School" philosophy (Ministry of Science and Education of Ukraine, 2019). In accordance with this philosophy, the goal has been set to make school comfortable and child-friendly, to adapt the learning process to modern living conditions. One of the tools which is going to be used is teaching robotics.

Among the main principles of the reform are the following: the formation of practical skills and competencies instead of abstract knowledge; use of modern teaching technologies; comfortable and interesting learning ecosystem.

It is also planned to fundamentally change the learning process itself, to pay special attention to such changes: gamification of the teaching process; increase of practical tasks; the introduction of integrated lessons; teamwork; collaborative learning; creating of a p2p-friendly atmosphere of mutual assistance

After analysing these approaches and making a comparison with the basic aims of school robotics (Eguchi, 2014; Scaradozzi, Sorbi, Pedale, Valzano, & Vergine, 2015) it was suggested to implement robotics into school curriculum, as an important tool for creating conditions for reforming the whole national educational system. Simultaneously with the introduction of such a toolkit, it is necessary to teach the upcoming teachers how to use robotics systems for educational purposes.

The necessity in creating of a methodical system of training for different categories of students — from elementary school students to students of pedagogical HEIs, upcoming teachers of IT is obvious.

At the South Ukrainian National Pedagogical University named after K. D. Ushynsky such investigation is carried out in two directions. The first direction is the bachelor degree program “Secondary education. Informatics" where robotics is introduced. In the framework of this program special courses of technical, programming and methodical training of the upcoming IT-teachers for introducing the elements of robotics into the teaching process in secondary school have been developed.

The second direction is carried out in the framework of extracurricular classes conducted for students of Odessa region, who are introduced to the basics of robotics and programming at the Department of Applied Mathematics and Informatics.

It is obvious that the process of introducing educational robotics is gradually and steadily approaching the development of generalized recommendations for the creation of teaching materials and technologies which allow teachers of any subject to use robots during their classes for the own didactical needs. And one of the serious issues that needs to be solved in each particular school or university is the problem of choosing the necessary and reasonable configuration of equipment according to the goals, capabilities and specifics of each educational institution.

In the current article, the issue of improving the approach to the formation of the equipment configuration, as part of an integrated methodological system, is considered.

Research Methodology

General Background

The task of choosing the best hardware configuration, due to the lack of clear ideas about the sought-after capabilities and necessary functions of robotic systems implemented in training, is poorly formalized. Furthermore, the state of art in application of robotics in the teaching depicts that there is no clear unambiguous algorithm for such selection. However, this kind of task is going to be adopted to the multitude of heterogeneous requirements of a particular educational institution, among which there is a group of non-formalized ones. All this leads to the conclusion of using the knowledge-based technologies to solve the current task.

Transferring recommendations of experts into the form of production rules allows automatically receive a recommendation regarding the most appropriate configuration option with taking into account the entire spectrum of heterogeneous and multidimensional requirements for a specific robotic laboratory — from didactical to economical ones.

Research Sample

The current investigation and development was based on using CLIPS. CLIPS is an expert system tool originally developed by the Software Technology Branch (STB), NASA/Lyndon B. Johnson Space Center. CLIPS is designed to facilitate the development of software to model human knowledge or expertise. There are three ways to represent knowledge in CLIPS: rules, which are primarily intended for heuristic knowledge based on experience; defunctions and generic functions, which are primarily intended for procedural knowledge; object-oriented programming, also primarily intended for procedural knowledge. The five generally accepted features of object-oriented programming are supported: classes, message-handlers, abstraction, encapsulation, inheritance, and polymorphism. Rules may pattern match on objects and facts. (Giarratano*, 2018*)

Various knowledge extraction methods were used to form a knowledge base: textual (analysis of methodical literature, technical documentation of various equipment, legislation base), active and passive communication methods (questionnaire, interview, brainstorming, lectures, dialogue).

In general, the rules used in the core of the prototype expert system are production rules depicted in the "IF THEN" pattern.

Research Instrument and Procedure

The prototype's knowledge base consists of a set of predefined facts and rules (so-called *deffacts* and *defrules*). The prototype has a text-based interface. Communication with the user passes in a mode of dialogue, which is based on yes-no questions. After the user has answered the questions, new facts are added to the knowledge base, the presence of which activates a set of rules responsible for the inference engine.

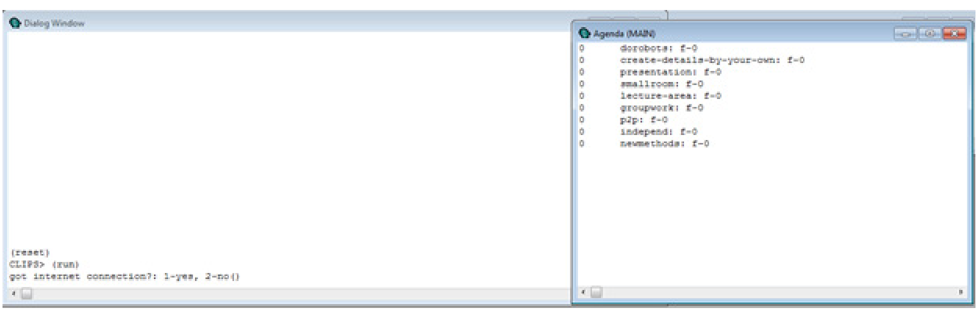

Figure 1. Dialog window and Agenda window.

It should be noted that during the development of the prototype, a conflict situation leading to the activation of several rules in the inference engine occurred. The recommendations proposed by the prototype based on conflicting rules are mutually exclusive. To solve this problem, a conflict resolution strategy was used, and several rules were added to the inference engine to extract from the knowledge base the list facts which could lead to conflicts.

Data Analysis

As a result of the development a prototype of the expert system was obtained, which is designed to make recommendations on the selection of equipment and the zoning of the ICR for conducting classes in robotics. Currently, work is underway to expand the knowledge base of this prototype and validate the rules in order to prevent the conflicts.

Research Results

To demonstrate the results of the work, we offer to get acquainted with the recommendations of the prototype, which were obtained during the trial work of the expert system (Table 1).

Table 1. Recommendations based on user's answers.

Questions	Answers	Recommendations
Got Internet Access?	Yes	Lecture area should be created Server station Is highly recommended Need projector and smartboard Soldering stations are recommended Need CNC Need PCs
Going to create parts by tour own?	Yes	
Got a small room for ICR?	No	
Going to organise a teamwork?	Yes	
Going to use Peer-Assessment, Brainstorming, etc.?	Yes	

The results obtained by the user, of course, are advisory in nature and are not a direct indication to action.

Conclusions and Implications

Thus, at this stage of the study, it can be concluded that the use of a knowledge-based adaptive approach to the rational selection of equipment for teaching a robotics classroom at school and its implementation as an expert system is relevant and in demand, as it provides an opportunity to get recommendations on equipping the robotics ICR to the non-expert user (school principal, city / regional / country authorities).

The use of knowledge-based approach and its implementation in the prototype of the expert system make it possible to obtain the necessary recommendations in a short time. At the same time, the likelihood of erroneous recommendations is extremely low due to the use of conflict resolution strategies.

Further development and research is the question of creating a valid and relevant knowledge base, filling it with rules that do not cause conflicts, supporting the work of this knowledge base and updating it in view of the rapid development of technologies and the appearance on the market of new devices and components which can be used in teaching robotics.

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A TUTOR'S PERSONAL AND PROFESSIONAL EXPERIENCES OF TUTORING IN A SCIENCE TEACHER EDUCATION MODULE

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Abstract

Student tutoring in innovative teaching and learning practices promotes personal and professional learning. Experiential learning theory underpins this research. An interpretive, qualitative approach and narrative strategy with purposive sampling was used. The tutor narrative accounts of tutoring the Research and Service-Learning module in Biological Science Education were compiled from a reflective diary, coordinator - tutor discussions and tutor notes. The qualitative data were analysed using descriptive content analysis. The tutor's self-confidence, language competence, understanding and application of research and Service-Learning and engagements with students were greatly improved.

Keywords: *experiential learning, pre-service teacher, teacher education, tutor's personal and professional experiences.*

Introduction

Pre-service teacher education in South African universities is expansive and policy driven. The Revised policy on the Minimum Requirements for Teacher Education Qualifications (Department of Higher Education and Training, 2015, p. 6), "is aimed at ensuring that the higher education system produces teachers of high quality, in line with the needs of the country,". Pre-service teacher professional development programmes are faced with increased numbers of students in the specialisation lecture groups and various support mechanisms are employed to enhance the teaching and learning, which include the employment of temporary contract module tutors.

The employment of tutors raises issues with regard to their interest, experience, competence, contextual and disciplinary knowledge including the specialised pedagogical content knowledge. Tutors are not ready-made individuals, so their development is linked to the module coordinator's understanding and practice of working with tutors, assumptions about teaching and learning particular specialised disciplines (modules) and also their beliefs about challenging traditional beliefs and practices. The partnership role between tutor and lecturer is one that is underplayed and yet it could influence the teaching and learning in the discipline (Layton & McKenna, 2015). Moreover, tutors, as postgraduate and undergraduate students are an essential component for the teaching of large groups of students, for effective working relationships for all students. Research in professional development internationally, mainly focuses on lecturer development and not tutor development or tutor experiential learning. According to Burge, Godinho, Knottenbelt and Loads (2017, p. 3), “None of this research has considered the experiences of tutors more holistically, thinking about how tutors feel and experience their roles. There is comparatively little knowledge about how tutors themselves see their professional development needs.” The research explored the experiential learning of a Biological Science for Educators 420 undergraduate module tutor through his observations and personal experiences of tutoring the module on Research and Service-Learning.

Literature Review

The use of a tutoring system in many universities and supplemental instruction in some, is an accepted process, especially with postgraduate students as tutors. Tutors were regarded as an “academic underclass” (Sharaff & Lessinger, 1994 cited in McCormack & Kelly, 2013, p. 94), this being the case over ten years ago, but their importance and value has increased over the years and they are critical to the teaching and assessment in any university (Beaton & Gilbert, 2013). In fact, the teaching and learning in a South African university would be negatively impacted on if no tutors were employed as contract staff, to teach. At this stage tutors are also engaged in online teaching and assessment in various subjects/specialisations for contact and distance learning students.

Research on tutors in the academic sector has focussed mainly on postgraduate students and the issues that they experience. These include an analysis of tutor support and development programmes (Chadha, 2013; Hall & Sutherland 2013); the female tutors and their needs (Starr, 2013); online tutoring and the requirements (Parker & Sumner, 2013); and the importance of policy development for tutoring and tutors (Gaskell, 2013) and in the South African context the issues of employment equity with regard to race, and South African citizenship.

The theoretical framework that underpins this research was experiential learning. Experiential learning in its simplest form may be defined as “learning from experience or learning by doing... immerses learners in an experience and then encourages reflection about the experience to develop new skills, new attitudes, or new ways of thinking” (Lewis & Williams, 1994, p. 5). Experiential learning is associated with constructivist theory of learning, as the “outcomes of the learning process are varied and often unpredictable” (Wurdinger, 2005, p. 69). The tutor’s engagement in the tutoring while learning how to tutor specialised content of research and Service-Learning was new territory for him, which he was eager to be engaged with in a space where he had to decide on how to conduct his role and the relationship with the students, the content and the context, and in the process observe his personal and professional development.

Research Methodology

An interpretive, qualitative research was undertaken to explore the undergraduate tutor’s experiential learning during the process of tutoring the Biological Sciences module. The module engages pre-service students in learning about research and Service-Learning and they are then expected to conduct research on their Service-Learning. Service-Learning is not volunteerism nor community service (Furco, 1996),

and with the pre-service teachers they were expected to provide service activities that did not entail teaching Life Sciences at a school or in any community organisation. So, the placement sites included old age homes, crèches, preschools, public gyms, children's homes. Service-Learning involved students in community service activities and their application of their experiences to their personal and academic development.
Fifty-eight Biological Sciences for Educators 420 (Bio 420) pre-service teachers participated in the Research and Service-Learning module. The pre-service teachers were engaged in the development of critical skills and community interactions and enhancement focused on their personal and professional development, so as to influence their work as future teachers. The module tutors were employed to support the pre-service teachers through consultations and informal interactions, inform the learning and assessment. In this research the module tutor was an undergraduate fourth year pre-service teacher who had completed and passed the module with a mark over 65%. Purposive sampling was undertaken, as the undergraduate tutor was the participant and researcher in the research.

The research is a narrative account of the tutor's observations and personal experiences of tutoring the module, over a period of 11 weeks. The experiences encountered by the tutor were written in a reflective diary and the research notes for each lecture session, in a notebook. Also, the informal discussions between the tutor and the module coordinator were recorded in a text format in the notebook as well. The data analysis using descriptive content analysis and the experiential framework indicated the data sets to be presented and discussed. As the tutor wanted to present the developmental nature of his learning, he presented it in three parts, as indicated in the findings section. The research rigour of credibility and dependability were worked with and the research ethics were considered and acted on.

Research Results

The findings obtained from the analysis of the data are presented in three parts, the student tutor's thoughts before the module, during the module and after the module.

Thoughts before the Module

My prime reason for wanting to be a tutor was for, "learning from this intense, different experience of tutoring, where research and Service-learning are integrated" (Reflective diary, 2016). Biological Sciences for Educators 420 (bio 420) is quite a different module compared to other biology modules offered in the School of Education. As a result, there was a lot that is required from anyone who is the tutor of the module. Lot of readings, long consultations with students asking for clarity in every step of their projects is what I will be engaged with. A reflective diary entry, "I never thought or saw myself as a tutor for this module and I think this was because of its different nature and I felt inadequate to advise others about how to conduct research". Another entry, "This module will really require a lot of time and reading, it is even worse this year because the class size is huge, there are 58 pre-service teachers in the class" (Reflective diary, 2016).

The thoughts that I had before the module also focused on my feelings and state of happiness that my application to be a tutor was accepted by the module coordinator.

The statement written, “What I am happy about is that the lecturer has accepted my application to be a tutor, as in her words she said that she sees potential in me and that from working with the students that I will also develop.” I also wrote about the gratitude that I have in that, “I am extremely grateful and happy that the lecturer of this calibre sees potential in me. This is so important for me as it gives me confidence and strength to work with students.” A further aspect that I focused on was that I was not alone in tutoring the pre-service students - I was to work with two other tutors: An Honours student and a fourth-year student.

Experiences during the Module

The experiences during the module focussed on incidences that were pertinent to the tutor’s learning and growth. These included the tutor attending lecture sessions and exploring student learning and attitudes during the module.

Tutors attending lecture sessions

Since I was expected to attend all the lecture sessions, I recorded in my reflective journal,

> “I feel that it is necessary that bio420 tutor/s should attend classes for their own benefits and student benefits as well. This is beneficial because tutors get to be on the same page with the lecturer to avoid cases where tutor and lecturer have contradicting thoughts about the same aspect of the module. This also ensures consistency in working between the tutor/s and lecturer” (Reflective diary, 2016).

I experienced that attending lectures was important for me to be aware of the developments in the module. I wrote, “I was aware of the personal learning of a number of things from both the lecturer, students and the lecture, that I did not know and also for some, which I had forgotten.” The lecture attendance was also important for the personal relationships with the students in that, “it helped me to develop a relationship with the students and to understand them better and it became easy for them to share the problems they encountered during the course of their project (research) with me.” The relationship building is a process which required time and close interaction with the pre-service teachers.

I observed the actions of the pre-service teachers during lectures and recorded, “they were well engaged, kept busy and challenged, sharing ideas and experiences but time was always a limiting factor.” What I found critical to the pre-service teachers’ development is that they were, “given opportunities to share their work/ideas/thought, but only a few responded.” I questioned this lack of participation, as I recalled how important my participation in the module was for my development as, “it helped me as a student to be able to ‘speak’ my thoughts and have confidence in sharing my thoughts with peers.” My learning from these observations was that I took the sharing of ideas as a crucial part of learning. Therefore, as a tutor I was focused on the wish that, “more students be given a platform to speak/share what they have written because it is beneficial for them.”

Student Attitudes and Learning

Students did not use a correct procedure for making appointments with tutors. They would see you on the taxi from Pinetown and ask you about their project and very few of them sent emails to make appointments. During the student reflection sessions, the peer tutor and I facilitated them. The module coordinator informed us and "she has a faith in us, she believed that we can work well with the students." (Reflective journal, 2016). The student learning was evident on the Research and Service-Learning Presentation day. During this day students showed a great impression while presenting their work, sat long hours listening to one another and it was the first time most students were engaged in experiencing such a long and intensive formal session. I think students showed tolerance and respect to one another. I believe that the presentation was one of the most well-planned aspects of this module and everything went accordingly. Some students though lacked confidence, as they had too much fear in such a way that it was difficult for them to even utter words. I think this should be taken seriously, not as a normal issue, the university should expose student in speaking in environment like this one, most student who have that problem are students who are coming from poor schools where there is a poor background of English.

Future Thoughts and Suggestions

Working with the module coordinator is always a great honour and privilege and I knew very well that whenever I went to her, I knew that she was going to say something either funny or serious, but it was always constructive and innovative. Tutoring this module was sometimes funny and interesting but in most cases the module was demanding, hectic, challenging especially towards the end we had to sit and mark 16-20 pages of student chapters. I sometimes sat for 1h 30 minutes dealing with one literature review.

I am grateful that I was given this opportunity of tutoring bio420 in 2016 and I call it an experience of a lifetime. Working with the coordinator in this module has grown me a lot, now I can confidently share my ideas, ask questions, for clarity if it necessary. All of this I could not do at first and "believe me it played and still has a very crucial role for me because it made learning to be very interesting to me." Module coordinator, you taught me to "make my life interesting", "learn to work with what you have" and "getting things done"

Conclusions

During this module I became aware that "I lack self-confidence (low self-esteem). This is because of my poor English background which causes me to be scared of speaking when there are many people, I feel that they know English better than I do" … "Towards the end of the module I ended up speaking without fear." (Reflective diary, 2016). This emotion is one that I have carried with me throughout the tutoring of this module. The work that I do with the students should be encouraging them for the development of self-confidence, be able to freely share their ideas and thoughts, including feelings; and to feel good doing it.

As a tutor, "I believe that I have grown and was tested in this module by being exposed in challenging situations - from the responsibility of presenting group sessions with the other tutors on Service-Learning, coordinating a reflective session with students and reading and editing their research report chapters." As a second language learner and as a future teacher who will teach Life Sciences in English – I am confident that the use of English and the exploration of meaning, developing the literacy in Science for learners will be a prime focus. This will further enhance my own literacy development and that of the learners. Furthermore, the use and assessment of the development of research knowledge and skills for students places me at a level of teacher as researcher where my practice will inform my theory about effective teaching, for enhancing learning of learners.

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EFFECTIVENESS IN THE DEVELOPMENT AND ACQUISITION OF MATHEMATICAL SKILLS IN CHILDREN IN RURAL AND URBAN PRESCHOOLS

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Abstract

The aim of the research was to determine whether geometric skills of the children in rural preschools are at the same level as those of their peers in urban preschools. The research included 352 preschool-age children (5 to 7 years old) residing in Poland, both in cities and the countryside. The measurements were carried out in the Biała Podlaska Laboratory of Psycho-Motor Skills. A SensoMotoric Instrument (SMI) eye tracking device and the i ViewX platform registering data with a frame rate of 250 Hz were used. The device has a special measurement system which tracks and records eye movements in a sequence and at a pace of an analyzed person. With a view to demonstrate the differences between the correctness of task performance and the place of residence of the children, a Pearson's Chi-squared test was performed. To evaluate the differences in the time of task execution, a single factor analysis of variance (ANOVA) and the Student's t-test for independent samples were employed. In all of the analyzed cases, the level of statistical significance adopted was p=.05.
The results of the research conducted on the studied group of children show that there are differences in the level of geometric skills between the children in rural and urban areas. It was established that a crucial factor which affected both the geometric knowledge and skills of the preschoolers were the place of residence, the age at which they started learning, and the duration of preschool education.
Keywords: *geometry teaching, mathematical skills, preschool-age child, preschool education*.

Introduction

The specific objectives and activities of Polish preschools are set out in the document referred to as the Core Curriculum (Guidelines) for Pre-school Education, authorized for use by the Polish Ministry for National Education (Journal of Laws of 24 February 2017, Item 356). This document states that the goal of didactic and educational work of preschools is to support child's development in all its spheres, i.e. the cognitive, social, physical and emotional one, while the target of the teachers working with preschool children is to prepare children to study in schools. Therefore, children graduating from preschools, irrespective of their place of residence, should acquire the same key competencies, i.e. mathematical, language, social, and motor competencies required to commence school education.

The key competencies enumerated in the Core Curriculum stress the importance of mathematical competencies as significantly affecting one's future school success.

It is worth to note that the quality of the process of competency development, both in preschool and school, is affected by a number of factors preconditioned by child's onto-genetic development and the family and school environments (Dixon, 2005; Kapur & Toh, 2013; Klim-Klimaszewska &Nazaruk, 2017). These include one's predisposition to learn (intelligence), interests, teachers' professional competencies, teaching methods, didactic aids, child's health condition, living environment, family situation, and many others.

Polish reports regarding educational maturity of 6-year-olds demonstrate large and clear relations between children's competencies, their living environment, and the level of parents' education (Frydrychowicz & Koźniewska, 2006). Studies conducted on all-Poland samples showed that preschool education had an impact on students' achievements in primary schools (Pregler & Wiatrak, 2011; Dąbrowski, 2015; La Freniere & Dumas, 1996).

The research presented the analyzed effect of cultural factors of the family and living environment on school successes of students in the early years of primary education. The conclusions drawn from the reports authorize me to claim that the optimum time spent in preschools is 3 to 4 years. It is particularly important for boys and girls of lower cultural potential in rural environments.

Against this background and on the basis of conducted research, the study is an attempt to address the major issue: do rural and urban preschools attain didactic goals (learning outcomes) set by the Core Curriculum at the same level? In other words, do the children from the countryside and from urban areas have equal educational opportunities and abilities? In this perspective, not only the place of residence but also the age at which a child begins his preschool education appear vital.

Having regard to the presented outline of the issues covered, a research project was carried out with a view to diagnosing mathematic competencies of children attending rural and urban preschools. The project was created with the cooperation of the Pope John Paul II State School of Higher Education in Biała Podlaska and preschools located across the city of Biała Podlaska and two rural communes of the Bialski Poviat. Due to the wide scope of the adopted research project, the research presents only partial results concerning the diagnosis of mathematical skills with respect to geometry.

The main research problem is laid down in the form of the following question:

Are the geometric skills of children in rural preschools at the same level as those of their peers in urban preschools?

The main research question is further detailed as follows:

1. What is the level of geometric skills in the studied children?
2. Are there any differences in children's achievements in geometry depending on preschool
location (in the countryside or in the city), and if so - what are they?
3. Can the age at which preschool education is commenced and its duration have a significant effect on the level of geometric skills?

Research Methodology

Participants

The research included 352 preschool-age children (5 to 7 years old) and was conducted upon the consent of parents and preschool management. The basic data regarding preschools, their location and the number of children participating in the study are set out in Table 1.

Table 1. Essential preschool data and the number of study participants.

Preschool name and location	Number of children		Number of children	
	N	%	*N*	%
Preschool No. 1 - Biała Podlaska city	52	14.78	254	72.16
Preschool No. 2 - Biała Podlaska city	80	22.72		
Preschool No. 3 - Biała Podlaska city	122	34.66		
Preschool No. 1 - rural commune in the Bialski Poviat	70	19.88	98	27.84
Preschool No. 2 - rural commune in the Bialski Poviat	28	7.96		
Total	352	100.00	352	100.00

Biała Podlaska is a small city with a population of just under 60 thousand people, located 30 km away from the border with the Republic of Belarus. It has a well-developed network of schools and other educational establishments, including preschools. The city is surrounded by typically agricultural communes, dominated by medium-sized individual farms. The rural areas across which the research was carried out has a very well-developed network of primary (elementary) schools. The preschool infrastructure, in contrast, is only now being intensively redeveloped.

Instrument and Procedures

The measurements were conducted in the Biała Podlaska Laboratory of Psycho-Motor Skills in Poland in June 2018. A SensoMotoric Instrument (SMI) eye tracking device and the i ViewX platform registering data with a frame rate of 250 Hz were used. Thanks to a special measurement system the device can track and record eye movements in a sequence and at a speed of an analyzed person. The analysis of research findings was performed with the application of BeGaze 3.4 (SMI) software. The sources of the addresses of the children and the length of their preschool education were their parents. The examination involved children observing a picture/scene on a computer screen comprising geometric figures and various objects, such as a house, a tree, and animals, and next having to find and identify a given geometric figure on the picture - depending on the task received. The tasks were designed on the basis of the Core Curriculum of

Preschool Education, which sets forth the key competencies of children graduating from preschools (Journal of Laws of 24 February 2017, Item 356). The contents and compositions of the tasks were appropriate to the age-specific physical and mental abilities of the children. When instructed by the teacher, children started to look for and point at geometric figures seen on the computer screen in the following task sequence:

Task 1: find and point at a circle in Picture 1;
Task 2: find and point at a triangle in Picture 2;
Task 3: find and point at a square in Picture 3;
Task 4: find and point at a rectangle in Picture 4;
Task 5: find and point at two identical triangles in Picture 5;
Task 6: find and point at two different-sized squares in Picture 6;

The scores for task completion were distributed as follows: correct answer: 1 point, incorrect or no answer: 0 points. Six correct answers (tasks) were awarded 6 points.

Data Analysis

The analysis of data obtained was based on, first of all, the evaluation of the results of task performance. The summary table shows first the tasks which were correctly performed and then the tasks which were either incorrectly performed or not performed at all.

With a view to demonstrate the differences between the correctness of task performance and urban/rural preschools, a Pearson's Chi-squared test was performed.

To evaluate the differences in the time of task execution, a single factor analysis of variance (ANOVA) and the Student's *t*-test for independent samples were employed. In all of the analyzed cases, the level of statistical significance adopted was $p=0.05$. The statistical analysis was performed using STATISTICA v. 13.1.

Research Results

With reference to the whole population of the children studied, the percentages of correct answers and incorrect answers per individual preschools located in the city and in the countryside were calculated.

Table 2. Answers given by children from individual preschools (*n*=352).

Task	Preschool	Answers correct		Answers incorrect		*p*
		Number of participants	%	Number of participants	%	
Task 1.	P. No. 1 city (*n*=52)	36	69.23	16	30.77	.94
	P. No. 2 city (*n*=80)	54	67.50	26	32.50	
	P. No. 3 city (*n*=122)	90	73.77	32	26.23	
	P.1. countryside (*n*=70)	48	68.57	22	31.43	
	P.2. countryside (*n*=28)	18	64.29	10	35.71	
χ^2 =0.79; *df*=4						
Task 2.	P. No. 1 city (*n*=52)	42	80.77	10	19.23	.001*
	P. No. 2 city (*n*=80)	42	52.50	28	47.50	
	P. No. 3 city (*n*=122)	88	72.13	34	27.87	
	P.1. countryside (*n*=70)	26	37.14	44	62.86	
	P.2. countryside (*n*=28)	12	42.86	16	57.14	
χ^2 =18.62; *df*=4						
Task 3.	P. No. 1 city (*n*=52)	46	88.46	6	11.54	.51
	P. No. 2 city (*n*=80)	68	85.00	12	15.00	
	P. No. 3 city (*n*=122)	106	86.89	16	13.11	
	P.1. countryside (*n*=70)	52	74.29	18	25.71	
	P.2. countryside (*n*=28)	24	85.71	4	14.29	
χ^2 =3.29; *df*=4						
Task 4.	P. No. 1 city (*n*=52)	46	88.46	6	11.54	.82
	P. No. 2 city (*n*=80)	74	92.50	6	7.50	
	P. No. 3 city (*n*=122)	112	91.80	10	8.20	
	P.1. countryside (*n*=70)	60	85.71	10	14.29	
	P.2. countryside (*n*=28)	24	85.71	4	14.29	
χ^2=1.53; *df*=4						
Task 5.	P. No. 1 city (*n*=52)	36	69.23	16	30.77	.26
	P. No. 2 city (*n*=80)	60	75.00	20	25.00	
	P. No. 3 city (*n*=122)	68	55.74	54	44.26	
	P.1. countryside (*n*=70)	44	62.86	26	37.14	
	P.2. countryside (*n*=28)	12	50.00	12	50.00	
χ^2=5.30; *df*=4						
Task 6.	P. No. 1 city (*n*=52)	24	46.15	28	53.85	.001*
	P. No. 2 city (*n*=80)	18	22.50	62	77.50	
	P. No. 3 city (*n*=122)	44	36.07	78	63.93	
	P.1. countryside (*n*=70)	50	71.43	20	28.57	
	P.2. countryside (*n*=28)	10	35.71	18	64.29	
χ^2 =20.03; *df*=4						

Note: P. No. 1; P. No. 2; P. No. 3 – abbreviations representing the name of preschools in a city; P.1; P.3 – abbreviations representing the name of preschools in the countryside; The numbering was adopted solely for the research objectives, to serve the purpose of anonymization of the studied environments.

* significant variability at $p < .05$

The results presented in Table 2 show that the geometric skills of children, based on the correct answers to individual tasks, are not equivalent. The research revealed differences between the preschools. Statistically significant differences were observed in the answers provided to Task 2 (finding and pointing at a triangle) and Task 6 (finding and pointing at two different-sized squares). Thus, it ought to be stated that children's skills in the field of recognizing plane shapes pose the greatest difficulties with respect to triangles. In addition, as far as the comparative analysis is concerned, the hardest turned out to be identifying two squares of different sizes.

Next, a comparative analysis of the test outcomes was performed (rural preschool children vs urban preschool children). The children were divided into two groups: 1 – children in urban preschools; 2 – children in rural preschools.

Table 3. Answers in the city vs countryside division (n=352).

Task	Preschool	Answers correct		Answers incorrect		*p*
		Number of participants	%	Number of participants	%	
Task 1.	Urban preschools (*n*=254)	180	70.87	74	29.13	.65
	Rural preschools (*n*=98)	66	67.35	32	32.65	
χ^2=0.21; *df*=1						
Task 2.	Urban preschools (*n*=254)	172	67.72	82	32.28	.001*
	Rural preschools (*n*=98)	38	38.78	60	61.22	
	χ^2=12.31; *df*=1					
Task 3.	Urban preschools (*n*=254)	220	86.61	34	13.39	.14
	Rural preschools (*n*=98)	76	77.55	22	22.45	
	χ^2=2.17; *df*=1					
Task 4.	Urban preschools (*n*=254)	232	91.34	22	8.66	.26
	Rural preschools (*n*=98)	84	85.71	12	14.29	
χ^2=1.22; *df*=1						
Task 5.	Urban preschools (*n*=254)	164	64.57	90	35.43	.51
	Rural preschools (*n*=98)	58	59.18	30	40.82	
χ^2=0.44; *df*=1						
Task 6.	Urban preschools (*n*=254)	86	33.86	168	66.14	.001*
	Rural preschools (*n*=98)	60	61.22	38	38.78	
	χ^2=10.91; *df*=1					

* significant variability at $p< .05$

The results presented in Table 3 demonstrate that in the case of five tasks, numbered 1 through 5, the urban preschool children performed better. In the last task, number 6, children from rural preschools performed significantly better than their urban preschool peers. The statistical analysis showed marked differences between the rural and urban preschool children in the answers provided to two tasks: task number 2 and task number 6.

Yet another objective was the analysis of children's mathematic achievements in the field of geometry having regard for the period of preschool education of children in the cities and in the countryside. In this case, the study included 130 children aged 7 who, within a few months, were to graduate from preschools and start primary school education. The research findings show that 41 children in the 7-year-old group attended preschools only for 1 year, i.e. only for the year preceding the school education. These were children living in the countryside. The remaining eighty-nine children aged 7 have been in preschools for two or three years. Hence, two groups were identified in order to compare answers to individual tasks: the first group included children who attended preschool only 1 year, in the countryside, whereas the second group encompassed children who attended preschool for more than a year. The results obtained are demonstrated in Table 4.

Table 4. Answers provided by the years of preschool education.

Task	Education group	Correct answers		Incorrect answers		*p*
		Number of participants	%	Number of participants	%	
Task 1.	2-3edu (*n*=89)	70	78.65	19	21.35	.32
	1edu (*n*=41)	29	70.73	12	29.27	
Task 2.	2-3edu (*n*=89)	66	74.16	23	25.84	.001*
	1edu (*n*=41)	15	36.59	26	63.41	
Task 3.	2-3edu (*n*=89)	83	93.26	6	6.74	.03*
	1edu (*n*=41)	33	80.49	8	19.51	
Task 4.	2-3edu (*n*=89)	83	93.26	6	6.74	.90
	1edu (*n*=41)	38	92.68	3	7.32	
Task 5.	2-3edu (*n*=89)	77	86.52	12	13.48	.03*
	1edu (*n*=41)	29	70.73	12	29.27	
Task 6.	2-3edu (*n*=89)	64	71.91	25	28.09	.04*
	1edu (*n*=41)	22	53.66	19	46.34	

* significant variability at $p < .05$

Data presented in Table 4 and the results of the Chi-squared test indicate that the children who started their preschool education earlier, i.e. attended preschools for two or three years, answered correctly to substantially more questions across all tasks. Significant statistical differences were noted in four tasks: Task 2, 3, 5, and 6.

Conclusions

On the basis of the analysis of the conducted research, conclusions have been drawn which will expand the area of academic research regarding the multi-dimensional nature of preschool education in the context of mathematical skill development in children. The conducted research has confirmed that, on the basis of geometric tasks, there are differences in the level of mathematical skills between children attending rural preschools and those attending urban ones. It is presumed that one of the reasons behind the differences may be the length of preschool education of the studied children. Preschool education of the selected group of 6- and 7-year-olds in the rural area started and lasted one year only. Unsatisfactory geometric performance diagnosed not only in rural but also in urban children at the stage of preschool education should be an important message to the teachers, above all, with respect to reflections upon the methods used when implementing the core curriculum. This is a practical tip for individualized exercises focusing on the development of children's intellectual potential.

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INFLUENCE OF PIAGET'S THEORY ON CONVINCING EXPERTS ABOUT THE DIFFICULTIES IN THE UNDERSTANDING OF SCIENTIFIC TERMS BY CHILDREN

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Abstract

In formal education, the teaching of natural sciences begins when children are about 12 years old. Teachers justify this with the difficulty and abstraction of concepts in these sciences, and they refer to the theory of child development by Piaget. However, numerous examples from everyday life, from non-formal education, analysis of the difficulties of individual terms as well as research in the field of mathematics and didactics of chemistry show that it is possible to teach natural science at lower stages of education.
Keywords: *Piaget's theory, teaching of natural science, formal education*.

Introduction

In Europe, science education begins when children reach the age of 12 (Grajkowski, Ostrowska and Poziomek, 2014). It is based on the belief that these subjects are difficult and require children's abstract thinking skills (Johnstone, 1991). According to the Piaget theory, the fourth stage of mental development (period of formal operations) is achieved by children at the age of 12 (Bee, 2004). This means that up to the age of 12, children's knowledge of natural sciences comes from informal and non-formal education. This knowledge may contain many inaccuracies and cause misunderstandings in the student's mind. This means that children may have difficulty accepting the new scientific meaning of words they have learned earlier. Such a situation makes it difficult for them to learn science. Research conducted in America by Sruggs and Mastropieri (1993) showed that more than 750 scientific words were introduced from kindergarten to sixth grade, and history does not differ in Europe.

The question then arises: Is it possible to teach science subjects at the lower levels of education? Considering the fact that according to research (Chiappetta, 1975), at the age of 12, at least 50% of children did not reach the fourth level of development according to Piaget's theory, it seems unreasonable to wait with the science of natural sciences to this age of children. On the other hand, numerous publications, for example in the field of mathematics, show that children reach certain skills earlier than planned Piaget (eg. the concept of "stability number"). There are also numerous publications on teaching chemistry and physics of young children. Non-formal education also shows that teaching science is possible at earlier stages of education (even in kindergarten or in grades 1-3 of primary school).

It seems that all these studies and reflections should result in the introduction of natural science (especially chemistry and physics) to the lower stages of formal education.

Research Methodology

The main goal of the research was to answer the question: *at what stage of formal education, particular terms in the field of sciences can be introduced.*

To answer the question posed, the research was carried out. The research was divided into three stages. *The first stage* from September 2018 to December 2018 were interviews with teachers. There were 10 discussions of about 25 teachers in the group (about 250 teachers took part in the research). During the discussion, conducted with the snowball technique, the teachers chose these concepts from the field of natural sciences, which they considered the most difficult. The concepts chosen by the teachers were analyzed in *the second part of the research* (in January and February 2019). Analyzing the didactic relationships on the concept maps, it was checked which terms are basic for learning. For these concepts, their definitions have been analyzed. Some concepts were chosen in pairs (when their definitions were similar, or when they had a similar use). Eight concepts were selected for further research (atom, cloud, electron cloud, proportion, electric current, wind, mathematical logic, programming / coding).

Justification for Choosing the Terms

The first chosen term was ATOM. It is a concept necessary to understand the structure of matter, which is why it is necessary for the teaching of chemistry and physics. Currently, in formal education, this term appears when children are about 12 years old. Although our previous research shows that it is possible to introduce this term earlier.

The second chosen concept was PROPORTION. The term is necessary and used in mathematics, physics, chemistry, and geography. This term in formal education appears late (7-8 class primary school), although children in everyday life often use it.

The next two selected terms: WIND and ELECTRIC CURRENT - have almost identical definitions but are introduced in formal education at various levels (4th grade and 7th grade of primary school). (Because the teachers of the term WIND consider it very easy and the term ELECTRIC CURRENT too difficult).

The following concepts were chosen on a similar basis: CLOUD and ELECTRON CLOUD, as well as the MATHEMATICAL LOGIC and PROGRAMMING. (Formerly programming was considered difficult but nowadays are programming courses for preschoolers.)

Experts were invited to *the third part of the study* (March 2019). This is due to the fact that experts are responsible for assigning content to the appropriate levels of formal education. Experts have been scientists dealing with didactics of natural sciences (conducting research in this field) and / or eminent teachers. A question-based questionnaire was used for the research. Experts were asked to answer 2 questions for each of the eight selected terms:

- *How old must children have to be able to enter the term '...' in formal education? (choice of one of the 5 responses),*
- *Is the term easy ... or very difficult. (5-step Likert scale).*

Research Results

The concept of ATOM has been considered by experts as moderately difficult. However, only 9 experts (out of 28) considered that this term should be introduced when children are between 13 and 15 years old. (That's how it is now in formal education.)

The term PROPORTION was also considered by experts as moderately difficult. 11 of them believe that the term can be introduced at the beginning of primary school education (in grades 1-3). However, as many as 13 think that the term can only be understood by older children (6 experts think that children should be more than 10 years old, another 6 experts believe that children should be older than 13 years and 1 of the experts thinks that only the student who has more than 16 years can understand this concept).

The concepts of WIND and ELECTRIC CURRENT have similar definitions:

- Wind - the movement of air masses caused by the difference in atmospheric pressures;
- Electric current - orderly movement of loads caused by the difference of electrical potentials.

However, the definition of wind is known to children much earlier than the definition of electric current. Experts consider the term WIND as an easy term, ELECTRIC CURRENT, as difficult or very difficult. As many as 14 experts believe that the term WIND can be introduced when children are between 3 and 6 years old. However, 13 experts believe that children must be 10-12 years old to teach about ELECTRICAL CURRENCY.

The terms CLOUD and ELECTRON CLOUD do not have a similar definition. However, using a comparison of the electron cloud with a cloud in the sky - we can explain this concept well. (The cloud has no visible boundaries - just like a cloud in an atom. Two smaller clouds can merge into a larger one - just as molecular bonds are formed. The formation of drops of rain from a blurred cloud is a good analogy showing the corpuscular-wave duality.) Despite the large parallels between the two concepts, the experts assessed them differently. 12 experts considered the term CLOUD easy to understand (after 8 very easy and medium difficulty). While 13 experts found the term ELECTRON CLOUD too difficult to understand (after 7 for medium difficult and extremely difficult). 15 experts found that the date of CLOUD can be already introduced in pre-primary education (3-6 years). Also, 15 experts felt that the term ELECTRON CLOUD can be made on formal education when children have more than 13 years.

A similar situation applies to a couple of concepts MATICATED LOGIC and CODING. Although experts consider both concepts to be moderately difficult, however, MATHEMATICAL LOGIC should be introduced at a later stage of education.

Table 1. Experts' answers regarding the difficulties of particular concepts.

	Atom	Propor-tion	Wind	Electric current	Cloud	Electron cloud	Mathemat-ical logic	Program-ming / coding
Very easy	0	0	7	1	8	0	0	0
Easy	8	9	**12**	5	**12**	1	3	4
Medium difficult	**12**	**13**	6	**11**	8	7	**11**	12
Difficult	6	6	3	**10**	0	**13**	9	7
Extremely difficult	2	0	0	1	0	7	5	5

Table 2. The experts' answers to the question: how many years must children have to enter a given concept.

	Atom	Proportion	Wind	Electric current	Cloud	Electron cloud	Mathematical logic	Programming / coding
3-6	1	2	**14**	1	**15**	0	3	4
7-9	**9**	11	8	9	9	4	5	7
10-12	**9**	6	6	**13**	4	9	8	**10**
13-15	**9**	6	0	5	0	**15**	**10**	5
16-18	0	1	0	0	0	0	2	2

Conclusions and Implications

Although the experts have current theoretical knowledge about the latest research and in their everyday practice use modern models of teaching - however, their beliefs about the difficulties of individual concepts have not changed. Therefore, the curriculum for teaching natural sciences is the same since the 1960s. The results of the research show that experts evaluate the difficulty of the concepts in a very different way. Especially these differences are visible in the case of terms with a similar definition (WIND & ELECTRICAL CIRCUIT) or in the case of analogical concepts (CLOUD & ELECTRON CLOUD). They believe that these concepts should be introduced at various stages of formal education.

The analysis of the difficulties in the definition of individual concepts as well as the analysis of their use in every day activities by children showed that there are no reasons to introduce some concepts earlier or later. It seems that the only reason for differences in the time of introducing the concept is the experts' habit.

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METACOGNITIVE INCIDENTS MANIFESTED BY STUDENTS OF YOUTH AND ADULT EDUCATION IN AN INVESTIGATIVE ACTIVITY

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Abstract

Practices that take into account youth and adult education (YAE) are still rare in the literature. The present work applied an investigative activity with YAE students from the last year of middle education, in the discipline of sciences, about the methods of construction of science and tests of variables. From the categorization of metacognitive incidents used, it was verified that the stimulus to the argumentation that the investigative activity potentiated was fundamental for the students to conclude the activity successfully.
Keywords: *adult education, investigative activities, youth education, metacognitive incidents.*

Introduction

In general, science education accompanies the political moment experienced in a country. With each new government happens a new reform that mainly reaches the levels of primary and secondary education. In Brazil, for example, during the 1950s and 1960s, science education was too technical, aiming to train scientists. This fact was a reflection of the Second World War that occurred, demanding the formation of professionals to act in the war research, for example (Krasilchik, 2000).

After redemocratization in Brazil in 1984 and the elaboration of the Brazilian Federal Constitution in 1988, science education again aimed at the critical formation of the citizen. In addition, it was also during this period that, in view of the progressive educational movements of the time, it instituted, for the first time in legal terms, the right to Basic Education, including those who did not have access to it in their own age, including, therefore, youth and adults education (YAE). In this sense, it is still relatively recent in the Brazilian context the assurance of the right of youngsters and adults to study (Santos, Bispo, & Omena, 2005).

However, there are still reports of the difficulty of pedagogical practices that meet the specificities of this public. Porcaro (2011) has pointed out that a recurrent problem in working with this public is the absence of places for discussion of a pedagogical proposal appropriate for this audience, which has specifics, requiring different treatment, and that works that point out strategies for this audience are still scarce. Thus, works that show adequate strategies for the public of the YAE are very important, in order to subsidize the teaching work in the science classes.

In this way, some works that discuss science teaching suggest that the discussions and the interactions within the classes are fundamental strategies to improve certain abilities, like the argumentation and the proposition of hypotheses (Altarugio, Diniz, & Locatelli, 2010; Gonçalves & Goi, 2018; Sasseron & Carvalho, 2013). Aslan (2019) also ponders out that the investigative activities, besides favoring the work of these abilities, can favor the learning of the conceptual contents of sciences.

On the other hand, assessing the development of these skills during a class using investigative strategy can be very subjective. Thus, the categorization of metacognitive incidents (Locatelli & Arroio, 2014) is shown as a possible tool to measure the manifestation of these abilities along an activity. The authors define as an incident the manifestation of a questioning or rethinking about something, the categories being defined as confirmation, monitoring, positive change and negative change. The confirmation incident is one that ratifies an idea, while the monitoring incident is related to the oversight of some concept. Positive change is a self-regulation directed towards an appropriateness to the idea taken for granted, whereas negative change would be a departure from the expected response. Even though, in this context, was chosen to use effective change instead of positive change, since it is believed that the word expresses the student's expected response more closely, as well as change in construction instead of negative change, because it translates from more objectively, the student's expected departure from the expected response. Thus, four metacognitive incidents were considered: confirmation, monitoring, effective change and change in construction.

From the above, the aim of this work was to identify the metacognitive incidents manifested by YAE students during the performance of an investigative activity on the hypothesis test during the scientific work.

Research Methodology

Data collection was carried out during a science class on methods of building science, lasting one hour and thirty minutes. The number of participants was 10 YAE students, between 18 and 57 years old, who attended the last grade of middle school, at night in a public school located in the city of São Paulo, Brazil. Three types of paper (sulfite, offset and carton), two types of yarn (string and nylon), two types of bladder (small and large) and two types of straw (normal and milkshake) were provided to the students. From these materials, the students were asked to answer the following question: "How to make the rail travel faster?"

The construction that should be done is to pass the wire (rail) inside the straw and then to glue the filled bladder, but not tied with tape, in the straw. The objective was for students to test the variables to arrive at the conclusion of which combination of materials would make the course faster, as seen in figure 1.

Figure 1. Scheme of the experiment developed.
(Source: Prepared by the authors).

In the present research only one of the participating groups was considered, with five students (A1, A2, A3, A4 and A5) in order to have the analysis done in depth. The choice of this particular group was due to the fact that they had the older participants and that they spent longer periods away from the classrooms. Student interactions during this process were recorded and then fully transcribed. The speech shifts were analyzed according to the categorization of metacognitive incidents proposed by Locatelli and Arroio (2014).

Research Results

The transcription of the group discussion during the activity resulted in 32 speech shifts. The argumentation among the students was fundamental for the group to be able to elaborate a hypothesis and to test the different variables that made up this experiment. Furthermore, all metacognitive incidents were manifested.

The speech shifts also showed that the metacognitive incident monitoring was very related to hypothesis proposition. This way, students monitored their ideas, with the help of the group, before proposing a new hypothesis. The results obtained also indicate that metacognitive incident effective change was overlapped with the monitoring by the group so that through the collective contributions that this incident was manifested.

In this sense, through the categorization of metacognitive incidents, it was possible to identify that the investigative activities potentiate the dialogue and the group argumentation, especially in the moments in which the students tested the variables, that is, the different materials, during the tests that performed. Therefore, skills that are expected to be improved during science classes, such as the hypothesis testing and assay were contemplated during the development of this activity.

The results showed that the research proposals in the science classes can help to promote these abilities, as other works of the literature point out.

Conclusions and Implications

From the analysis of the obtained data, the investigative activity made possible the manifestation of the four categories proposed by the theoretical reference. Through the interactions evidenced by the speech shifts, it is observed that the dialogue among the participants was nerve-wracking so that the group analyzed the approached expected response.

In addition, the variable test process shared by the group of students was privileged by the argumentative process built throughout the activity, evidencing the importance of the investigative process for this construction.

As future works, it is suggested to carry out investigative activities with other publics, in order to evaluate if the strategy favors the manifestation of metacognitive incidents as well as the YAE students.

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SCIENCE LARGE-SCALE ASSESSMENT ALIGNMENT TO THE REVISED SCIENCE CURRICULUM

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Abstract

The research compared and assessed 6th grade student large-scale assessment item indicators according to the revised competency-based Science curriculum in Latvia, in order to understand what improvements are needed in the large-scale assessment for aligning the national assessments with the new national curriculum, and thus ensuring successful implementation of the educational reform. The theoretical framework of the research was developed by using the frameworks of the Programme for International Student Assessment (PISA), and cognitive level was measured according to the Structure of Observed Learning Outcomes (SOLO) taxonomy.
Keywords: *assessment alignment to curriculum, educational reform, scientific literacy*.

Introduction

Similarly as other countries around the world, Latvia undergoes a nation-wide curriculum reform in general education with an aim to develop 21st century skills. The reform focuses on the development of learners' competencies – the ability to apply knowledge, skills, attitudes and values to various contexts, complex and changing real life situations (OECD, 2016). Scientific literacy is one of the key competencies for the 21st century learner (OECD, 2018), and it is defined as one of the learning goals that should be achieved at the end of the compulsory education in Latvia -Grade 9 (Regulation No.747, 2018).

To support successful implementation of the reform, the alignment of the curriculum with pedagogy and assessment plays a crucial role (Fullan & Quinn, 2015). Previous research (France et al., 2017; Pestovs & Namsone, 2018) indicated that there is a difference between the learning content defined in the national curriculum and the learning content that is assessed in the national tests. Thus, the analysis of national tests and the degree to which the assessment is aligned to the new curriculum characterises success regarding the accomplishment of the reform aims.

The purpose of the research was to review and evaluate 6th Grade national level tests in Science subject for two consecutive years – 2018 and 2019 in the context of the new curriculum. The main aim of the analysis was to gain an insight into the conditions significant for successful reform implementation.

The theoretical framework with regard to the definition of scientific literacy was based on the OECD's (Organisation for Economic Co-operation and Development) PISA

(Programme for International Student Assessment) Science assessment framework, and the definition of the item cognitive demand – on the SOLO (Structure of Observed Learning Outcomes) taxonomy (Biggs & Collis, 1982).

To achieve the purpose, the following research questions were identified:

1. What are the assessment indicators in 6th Grade national tests in Science in 2 years' period in Latvia?
2. Are there any changes between the years?
3. To what extent the aspects measured in the national tests align with the revised curriculum?

Research Methodology

National level tests of years 2018 and 2019 were analysed by specially trained experts, individually and in focus group discussions. Firstly, the assessment indicators were determined individually, and then during several (at least three) iterations in a group setting the assessment indicators were revised and the cognitive level of each item according to the SOLO was defined. Additionally, for several items student answers were analysed to understand what answers were accepted during the marking, as national level tests were administrated and marked internally in schools.

The assessment indicators of national level tests in Science were mapped according to the (a) scientific literacy categories (that represent the new curriculum) and (b) SOLO cognitive levels (I, II, III, IV).

The limitations of the research methodology were that there was an evidence of inconsistency between the item cognitive demand and the school interim marking, which in fact reduces the cognitive demand of the item. For some items experts could not define the assessment indicator and these items were excluded from the research.

Research Results

As Table 1 demonstrates, most assessment indicators in Science national level test in 2019 were identified at SOLO II and I levels, while only 3 items (from 23) were identified at SOLO III level. Assessment indicators for items 19 and 22 were not defined, and items were omitted from the analysis, because of the inconsistency in decisions about assessment indicators. By comparison, from all 30 assessment indicators in Science national level test in 2018 only 1 item was identified at SOLO III level, the rest - SOLO II and I levels (see Table 2).

Table 1. Item assessment indicators of 6th grade national level test in Science, Year 2019.

Item No.	Assessment Indicators	SOLO levels
1.	Calculates the time from minutes to seconds	I
2.	Deduces the Moon phase by modelling	II
3.	Knows why the day and night shifts	I
4.	Knows how to verify that there is air in the room	III
5.	Determines scale according to the stated conditions	I
6.	Knows the necessary equipment for filtering	II
7.	Recognizes the mixture, which can be filtered	I
8.	Recognizes the condition for the faster evaporation	I
9.	Knows what is dissolution	I
10.	Knows how to speed up the dissolution process	II
11.	Compares the numbers to determine the biggest ratio solute in the solution	II
12.	Recognizes the described observation	II
13.	Recognizes common used material properties	II
14.	Determines the distance by extrapolating the linear graphic	II
15.	Deduces the length from the graphic	I
16.	Recognizes a working electric circuit	III
17.	Explains the phenomenon of using observation and gas volume dependence of temperature	I
18.	Knows renewable energy sources	II
20.	Recognizes plant by indications	II
21.	Recognizes parts of plants shown in the figure	II
23.	Predicts in a particular example the three elements of ecosystem dependency and the consequences of one element of change	II
24.	Compares values to make the reliable conclusion	II
25.	Interprets complex graphical information	III

Table 2. Item assessment indicators of 6th grade national level test in Science, Year 2018.

Item No.	Assessment Indicators	SOLO levels
1.	Determines the lowest value by comparing the complex by analysing the information	I
2.	Recognizes the relation between the concepts of "density" and "mass" and "volume"	I
3.	Find the largest number in the table	I
4.	Evaluate the way the data is displayed according to the obtained data	II
5.	Determines the highest value by comparing the complex by analysing the information	I
6.	Reads the values from the bar chart and the value from the graph to complex graphical information.	I
7.	Know that the type of precipitation depends on the temperature.	II
8.	Interprets graphical information in a specific (biology) context, evaluating the relevance of statements to interpretation	II
9.	Reads the volume of liquid using the drawing of a measuring cylinder	II
10.	Recognizes supportive, nervous, circulatory and respiratory systems by image	I
11.	Knows the oceans and seas are saltwater	II
12.	Knows from which side the sunrise takes place in the northern hemisphere of the Earth	I
13.	Reads the largest and smallest sector from the chart	III
14.	Interprets bar chart data in context (astronomy) to form a verbal relationship	I
15.	Knows the Moon Phase succession and appearance	I
16.	Recognizes the smallest value from the bar chart	II
17.	Knows the biggest causes of pollution	I
18.	Knows how to conserve natural resources	I
19.	Knows an example of action that leads to a reduction in air pollution	I
20.	Knows that sunglasses protect your eyes from light and ultraviolet radiation	I
21.	Knows renewables and non-renewable energy sources	I
22.	Knows the change of pole length depending on the time of day	I
23.	Transforms the data in a graphical way	I
24.	Finds and reads information	II
25.	Knows that the experiment should be repeated three times to calculate the mean value	II
26.	Knows that the dependent variable should be changed	II
27.	Finds and reads information	II
28.	Finds and reads literally found different information	II
29.	Determines the appropriate graphical representation according to the scale.	II
30.	Set higher values by analysing complex graphical information	II

Table 3. Alignment between item assessment indicators of 6th grade national level tests in Science and the revised curriculum framework.

	Competence	SOLO level							
		I		II		III		IV	
		Year 2018	Year 2019	Year 2018	Year 2019	Year 2018	Year 2019	Year 2018	Year 2019
Scientific literacy	*Explain phenomena scientifically*		18, 16, 10, 9, 8, 4		13, 7, 23, 2, 3		17		
	Interpret data and evidence scientifically	3, 14, 22, 23	1	4, 8, 11, 13, 24, 27, 28, 29, 30	21, 20, 14, 11, 15	16	25, 5		
	Evaluate and design scientific enquiry	1, 5, 6	6	7, 9, 25, 26	13, 24				

Assessment indicators of 2018 and 2019 Science national level tests demonstrated inconsistency in two-year period both in scientific literacy competencies and SOLO levels. Most indicators matched with "interpreting data and evidence scientifically". According to the SOLO levels, during two-year period only 4 items were identified at SOLO III level, and there are no items identified at SOLO IV level, which is critically important for the knowledge transfer and conceptual understanding as student learning result.

Conclusions and Implications

Assessment indicators identified in the national level tests of the two last years match against the three scientific literacy competencies, but to a different extent both in terms of balance, as well as cognitive depth. However, there are considerable changes between the Year 2018 and Year 2019 with regard to the assessment of scientific literacy competencies. For example, in the Year 2018 there are no items assessing student competence to explain phenomena scientifically, but in the Year 2019 there are 12 items assessing it. This leads to the inconsistency of the result interpretations by teachers and policy makers.

Item assessment indicators reveal that the most substantial part of the assessment items assesses lower cognitive skills according to the SOLO. This implicates a huge disparity between the revised science curriculum and the assessment, as one of the main goals of the curriculum reform is to enable students to demonstrate the ability to solve problems and deal with complex situations. Thus, the research indicates the need for a better alignment between the learning content in the new curriculum and the assessment, in order to ensure successful reform implementation.

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EUROPEAN AUGMENTED REALITY TRAINING NEEDS

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Abstract

The report of AROMA project (AROMA project consortium, 2018) summarizes a detailed study performed within project partner countries (Belgium, Czech Republic, Greece, Malta, Romania, Spain and Sweden) aimed at identifying the training needs connected with augmented reality technology (AR) and entrepreneurial skills and mapping an awareness about the AR technology. For the project, the research also serves as a first step to identify gaps that need to be addressed to offer a holistic syllabus integrating AR with selected skills and competencies.
Keywords: *augmented reality, competencies for entrepreneurship, vocational education and training.*

Introduction

The Erasmus+ KA2 AROMA project (Digital Training Toolbox for Entrepreneurial Training in Augmented Reality, No. 2017-1-CZ01-KA202-035560) is motivated by the EU's Entrepreneurship 2020 Action Plan. The digital world is developing novel technologies that can offer a range of opportunities for businesses in the knowledge-based economy and also for education. These trends reflect a need that vocational education (VET) training in appropriate skills should also focus on exploiting digital technologies to help foster new business opportunities and raise general awareness about the potential of some digital technologies, namely the AR, which can help to enhance key competencies such as digital skills, entrepreneurship, lifelong learning, decision making etc. The AR technology itself has a potential that can be exploited in various fields and many training and educational activities – see also e.g. (Akçayır & Akçayır, 2017; Chang & Hwang, 2018; Chen, & Wang, 2015; Ibáñez & Delgado-Kloos, 2018; Chen & Wang, 2015; Lamanauskas, 2008; Lincoln, 2018; Yip, et al., 2018). Therefore, it can be interesting and important to map the overall awareness about the technology among VET trainers, its possible exploitation for the training in various contexts and if or how it could help to develop some selected competencies closely connected with entrepreneurship.

Research Methodology

The survey had two essential parts. The first one was an online anonymous questionnaire including 15 questions grouped into 3 sections: respondent background, knowledge of the AR technology and evaluation of the importance of the EU key competencies and skills to develop entrepreneurship (European Commission, 2017). The aim was to reach a wide spectrum of respondents from VET trainers to entrepreneurs and stakeholders with various fields of their specialisations. Totally, answers from 322 respondents have been collected. The second part of the survey consisted from 31 deep interviews gaining the views, experience and opinions of 19 VET trainers and also some engineers, entrepreneurs, personnel agency specialists, an ICT specialist and an international relations specialist. The questionnaire was evaluated through a spreadsheet with graphs for most survey items. All the interviews were transcript into the report (AROMA project consortium, 2018), in which only the country, the gender and professional background of the respondent are noted. Then, the common and overall views and suggestions were summarized.

Research Results

Among the EU competencies most appreciated were digital skills, learning to learn (willing to learn) and creativity (see Figure 1). In connection with the competencies to promote entrepreneurship (Figure 2), some respondents pointed out that all are important and each of the selected competencies should be developed at some minimal level. The main obstacles for more extensive employing of the AR in training and education were the money (needed for hardware like glasses as well as for the software and experts developing the AR content). Also, it was pointed out the importance to keep the courses updated and follow the fast development of technology. As many teachers and trainers prefer to create the course materials themselves, it is crucial to train them and provide them with suitable motivating support to overcome starting difficulties when they make the first acquaintance with some technical details.

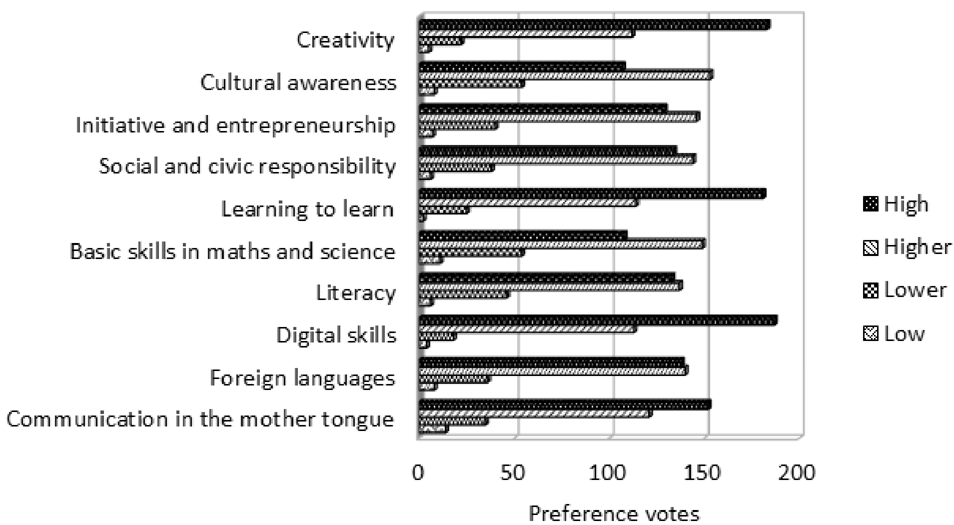

Figure 1. The importance of the EU key competencies.

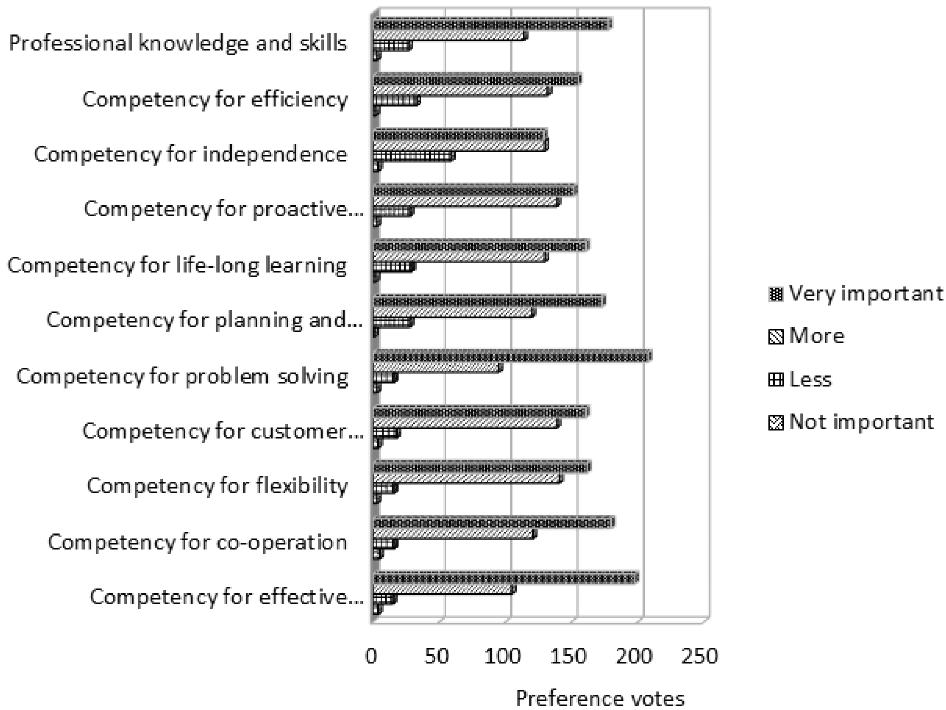

Figure 2. Importance of selected competencies to develop entrepreneurship

Conclusions

Though the AR technology gradually finds its way into business, education and common life, it can be still considered relatively unknown. Our respondents expect, that AR technology could accelerate training, increase its efficiency, make learning and training more dynamic and enabling to solve some problems faster. The most promising and effective ways how to promote the AR technology are sharing information online (e.g. via social media) and by presenting the best examples of how to use it profitably in practice. The training of teachers is very important for larger exploitation of the AR technology in education. Our survey also confirms the general importance of the key EU competencies and the selected competencies to develop entrepreneurship.

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ASSESSMENT IN CADETS' TECHNOLOGY COURSE

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Abstract

In many technology related courses in addition to the new content, previously learned knowledge about science and science related supportive tools are simultaneously studied. In the field of applied sciences, the aim is to apply technology applications derived from these scientific methods and models to the operating environment. From the point of view technical disciplines in cadets' education are important but narrow in scope, so there is a need to look for solutions that meet the educational goals of the local community. In this research, it is considered to build a broader assessment, to support learning to be motivating, and also to guide teachers at their work. This empirical research consists of findings from three successive courses in the sensor technology education for cadets. Examination structure is analyzed according to the test scoring and student success. As a conclusion, a course of specific mix of quiz can be recommended. Moreover, the principles of the presented form-based test are transferable to electronic assessment environments.
Keywords: *structure of assessment, summative test, technology education*.

Introduction

The National Defense University (NDU) is a training institution responsible for educating the future leaders of Finland's armed forces and Border Guard. Due to a clear link to work life, training can emphasize professional aspects and, in particular, the practical skills required in the first job. Nevertheless, the education should take into account academic research and general capacity building for lifelong skill development. Also, efforts have been made to reform the structure of the training for organizational needs or for the external reasons. The latter include the Bologna process or the Karvi audit (Karvi, 2017). This study discusses the teaching and development of specific surveillance and target accusation course. Findings from previous implementations of the course have been discussed earlier (Rissanen, 2010, 2014). This research focuses on students' assessment in three successive courses in years 2014–2016. As a formative assessment, cadets' learning was monitored through colloquial discussions and short exercise assignments related to lectures. In the end of the course a summative test was held for grading.

Evaluation as Part of Teaching

University learning is aimed to a permanent change that can be derived from the student's personal work during the course. In general, the first step is to use assessment tools to collect information on student learning (measurement) and then to evaluate each student's learning level (assessment) (Snowman, McCown, & Biehler, 2008). In the military context, most of the courses include a number of learning objectives, some of which can be considered as tacit knowledge, which is difficult to measure without real [military] activity and the real threats associated with it. Anderson's and Krathwohl's (2001) taxonomy classifies learning types with verbs, separating lower-level skills (remember, understand) and higher levels (applying, analyzing, evaluating, creating) from each other. The basic level of military technology knowledge is based on the transformation of remembrance into understanding and later on to the ability to apply key information. Technological education defines the process of technology and leads to identify relevant problems for solving.

Over its basic function an exam could also support other educational aspects such as long-term learning, creative thinking, and motivation. In that task it would be fine to provide proof of competence and assessing its level using a real operating environment. However, larger groups of students for whom applied exercises are limited due to resource allocation must be satisfied with traditional tests. A versatile exam structure can motivate and inspire students. In practice, several types of exams are required. Often, the course content controls which types of tests produce the best overall outcome. In practice, the aim is to find a solution that reliably measures learning but is equally easy for an inspector to write reviews and grades for students. The development of evaluation must be seen as part of better education.

Research question 1. What new information did the analysis of the case course provide for the development of the assessment?

Research question 2. How can the results be taken into account in the development of the evaluation?

Research Methodology

The focus of action research is on the influence of action and on the participation and involvement of researchers in the organization's everyday life. Attendance is combined with subject analysis and influencing into practice. Kemmis and McTaggart (2000) emphasized that in reality the process may not be as straightforward as sequential parts of independent design, operation, observation and reflection. The described modules may overlap, and the original plans may become obsolete based on experience and new information. In O'Leary's (2004) model, action research was seen as an experimental learning approach, with goals including refining the needs of the methods, knowledge, and interpretations based on the understanding of previous cycles. In this research three successive cycles were given. Interventions were made to proceed towards a better assessment of learning outcomes.

Research Setting

The exams should measure the student's skills and also support students' learning in the long term, provide the teacher with information on how to continue the course, but also lead to the plans that balance the workload of the teacher. Occasionally, students' and the teacher's perception of the learning goal may differ. For this reason, in the case of large entities, the teacher strives to focus on key areas. Guskey, (2000) has pointed out that lazy students may complain that the tips of the offered reading list did not match so that it would be easy to complete the whole course, and even with great honors. For this reason, giving straight tips to the test is not entirely meaningful.

A well-prepared assessment reflects the concepts, knowledge and skills that the teacher has emphasized in the classroom, in the textbooks, and in the learning material portal. The selected criteria for assessing student performance must be adapted to reflect the chosen approach. Under such conditions, an exam based on learning would not surprise students. Desired learning goals must be achievable for students and the course evaluation is one of the elements in the process. Instead of "teaching to the test", one should evaluate what is taught and by what means. A good overall assessment of the situation serves as a meaningful source of information for teachers, helping them identify what they taught well and what they need to do (better) next time. (Guskey, 2003)

Occasionally, the estimate of the development may be a simple summary of how many students did not complete the performance at each assessment point or did not meet the pre-set criteria. When looking at these results, it is necessary to look at the quality of the assessment elements or criterion. Is the question ambiguous or unclear? Did the students misinterpret the question or what was meant to be measured?

Structure of the Final Exam

During the study the summative test consisted of 5 elements with light variation in amount and theme. The elements were:

- Explain concept, meaning and application which can be expressed in no more than five sentences, picked up from the content and lessons.
- Short answer. (This was wider than just explain concept, e.g. compare two items).
- Claim or statement (True / false).
- Task partition: Explain on the basis of the image.
- Task part: -essay or calculation task.

Yearly the exam was repeated at least twice based on each year's lecturing material. For clarity reasons major part of the tasks were repeated year after year. Even though theme was not changed, light modifications were done e.g. for clarity reasons. As an example, two clear images types were utilized in the explain image section. The first one was the diagram of the Planck model of black body radiant heat as a function of source temperature. Usually the image contained four curves in the logarithmic scale. Identifying the image and naming the items using the Wien's displacement law was enough for an accepted solution. The model answer included extra points for additional information. The other commonly asked image type showed atmospheric attenuation from UV radiation up to 15 μm. The aim here was to remember this very often repeated concept and to verify scale for visible light in the spectrum and also the so-called atmospheric windows. Both tasks required some insight, but the tips students could utilize were provided as correct information within the exam leaflet's other parts. On the other hand, a broader essay task without quantitative delineation produced a lot of text and thus it was a burden to the teacher. Therefore, lot of preset structural order requirements and guidance were set to normalize answers. The alternative calculation was simple to grade but turned out less popular among students.

Research Results

The course and the examination were considered difficult. According to some students, it did not test every major theme from the course description. To analyze interventions, the student success in each section of the exam was listed and there after compared in three successive lecturing years. The listed details needed additional analysis from the instructors' observations and students' evaluation of teaching (SET).

Table 1 shows the six sections of the final exam in the technology course. Question types were listed as the guiding column. Each row showed: student group's average record in the specific question section, next the maximum score, and finally relative success (%). Because there were variations in the number of subtasks and the detailed structure of tasks in each year, only the relative values were compatible. The percentage value was determined by dividing the average score by the maximum reachable value given by the assessment model's data.

Table 1. Test scoring and student success in three different years.

	2014			2015			2016		
Question types	**Average**	**max**	**(%)**	**average**	**max**	**(%)**	**average**	**Max**	**(%)**
Explain concepts	4.9	6	82	4	7	53	4.5	7	64
Short answers	2.2	4	54	3.2	4	81	5.7	6	96
Claims(true/false)	12.5	16	78	15	20	76	18.2	22	83
Picture 1	1.3	4	31	2.3	6	37	3.4	7	48
Picture 2	2.1	4	53	4	6	62	3.7	8	46
Essee or calculus	7.1	12	59	5.7	10	57	6.1	12	56

Major finding was that a broader, detail full, and scaled-up test seemed to collect better results of knowledge even when the student's knowledge includes a non-organized set of individual knowledge and skills. Set of individual students' previous success was compared to the answers in this exam. In this case, a student who was uncertain about his / her knowledge, as the test progressed, worked on his knowledge. Therefore, he was able to exceed the critical limit to obtain such a score that he has passed the exam or even gained a little better grade than that. This finding was also positive, because expanding the number of tasks for each individual sup-part of the examination did not remarkably affect average grades.

Conclusions and Implications

This research pondered how the analysis of the assessment part of the sample technology course provided information on NDU's technology education arrangements. Because this research utilized only on narrow part of the technology education and the observations were made only in three successive years, the data is beyond of wider generalization. So even though the material described in the study is large *(N* = 369) variation of parameters is limited. It seems that a summative test of 5 elements gave students more options to show their gained knowledge. But this is only a recommendation for further research where students' profile would guide what type of efforts will be selected to show knowledge and skill in the assessment. The findings include the option to export this form based (or paper and pen type) examination into a portal- based variant for a same type of course.

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COMBINED MEASURES OF STUDENTS' SUCCESS: RECENT TRENDS AND DEVELOPMENTS IN SCIENCE EDUCATION RESEARCH

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Abstract

Besides measures of students' performances, a valid assessment of students' efficiency in a teaching process should also include measures of invested mental effort. The research presented herein covers several approaches in measuring students' mental effort including 5, 7 and 9-point Likert type scales, time on task, as well as eye tracking technique which in combination with performance measures provide valid information on students' success. Results of the research showed good correlation between mental effort assessed by 7 and 5-point Likert type scales and students' performance, while the use of the 9-point scale showed a low degree of correlation, thus recommending the use of a scales with 5 and 7 points for educational purposes over 9-point scales. The research presented herein illustrates how eye tracking can be used to support the evaluation of invested mental effort. Additionally, this method enabled the identification of some student difficulties in the analyzed area – Stereochemistry.
Keywords: *efficiency measure, mental effort, students' performance, science education*.

Introduction

Over the years a vast majority of researchers performed their research on students' efficiency in teaching process relying only on measures of students' performances. However, although such measures provide valuable information about the effectiveness of the teaching process, they cannot be its only indicator. It is found that one also has to take into account the basic idea of Cognitive Load Theory (Paas & van Merrienboer, 1993) about the limited capacity of the working memory. Accordingly, research showed an increasing interest in cognitive load measures in recent years, and in particular, measures of its important construct – mental effort.

There have been developed various approaches to measuring mental effort. The main classification of mental effort measures implies subjective and objective approach. The objective approach is mainly based on physiological and behavioural measures. Some of the most common techniques used within this framework are eye tracking technique (Baluyut & Holme, 2019; Tang & Pienta, 2012), brain activity measurement (Whelan, 2007) and measurements of cardiovascular indicators (Paas & Merrienboer, 1994).

Subjective measures are the most frequently applied empirical methods for measuring mental effort in science education research. They are based on the assumption that people are able to revise their cognitive processes and assign a numerical value to the invested mental effort (Paas et al., 2003). Subjective measures are usually based on the use of scales such as the Likert type scale. Their usage as a reliable measurement instrument for assessing the invested mental effort is very-well documented in the literature (Ayres, 2006; Kalyuga, Chandler, & Sweller, 2000; Kalyuga, Chandler, & Sweller, 2001; Tindall-Ford, Chandler, & Sweller, 1997). The above-mentioned authors suggest that such measures are the most reliable and most sensitive to detect relatively small differences in mental effort. In addition, such measures highly correlate with objective measures.

Modern trends in the assessment of efficiency include both performance and mental effort measures. One of the affirmed approaches in modelling the relation between performance and mental effort was proposed by Paas and van Merrienboer (1993). This model made it possible to determine, in a relatively simple way, the relation between performance and mental effort, that is, the combined effect of these two indicators on students' efficiency.

The aim of this research was to compare various approaches in measuring students' mental effort (subjective – Likert type scales and objective: time on task and eye-tracking) as well as to combine them with measures of performance to provide valid information on students' efficiency.

Research Methodology

The research was carried out in several stages:

(i) Application of 5, 7- and 9-point Likert type scales and determining which of the scales is the most sensitive in evaluating the mental effort.

(ii) Measuring the time necessary for the task to be solved.

(iii) Employing the eye tracking methodology to provide information on the invested mental effort.

(iv) Combining measures of performance and mental effort, thus providing information about instructional efficiency (main study).

Different stages of the research included different research samples. Thus, the first stage of the research included 62 secondary school students aged 15 to 16. The second and third included 17 students majoring in chemistry teaching from the Faculty of Sciences, University of Novi Sad, who were in their final year of the Bachelor studies. The last (main) stage included 189 secondary school students from Novi Sad (Serbia).

Research instruments were designed according to the objectives of individual studies. The first stage of research included 3 tests with 6 items, belonging to the teaching topic Dispersions. All three tests had analogous tasks, the design of which was identical, and the only difference could be found in numerical values and types of substances used. It is important to note that the first test included a 5-point Likert type scale, the second included 7-point scale, while the third included 9-point Likert type scale. This kind of design enabled a direct comparison of the sensitivity of the applied scales. The second and third stage of the research included an online test with 6 items, which belonged to the teaching topic Stereochemistry. The instrument used in the main stage included 15 two-tier items, covering the topics: Group 14, 15, 16 and 17 Elements.

All the participants, included in the research, accepted to willingly participate without any constraint or expectation of reward. All necessary permissions were obtained prior to research.

Research Results

Results of the first stage of research showed that 7-point Likert type scale correlated best with students' performance, while the 9-point scale showed poor correlation. Such results indicated justification of the use of 7-point scales in research designs. Poor correlation in the case of a 9-point scale could be explained by the fact that students were not able to evaluate fine differences in the mental effort (for instance nuances between very difficult and extremely difficult). A 5-point scale gave satisfactory correlation values which can be explained by the fact that students are familiar with such a way of evaluation due to the same way of grading (1 to 5) in the school system. These results are significant because they show that by selecting a scale of the appropriate range we allow students to reflect on their mental processes and to determine the amount of invested mental effort by assigning it a numerical value. In addition, these results support the application of subjective methods of evaluation of mental effort as convenient non-intrusive tools in educational research designs.

The following stage of the research was focused on measuring the time needed to solve the task as well as on the results of eye tracking analysis. This powerful method enabled us to monitor the individual steps of the problem-solving procedure, to examine how much time is spent on various aspects of the task, as well as to keep track of revisited student's fixations. This approach allowed us to determine what are the difficulties that students encounter within Stereochemistry, which impose the investment of a large amount of mental effort. Some of the identified difficulties involved the determination of the chirality of the molecules, as well as the absolute configuration of atoms in both acyclic and cyclic structures.

Last but not least, combined measures of performance and mental effort provided valid information on instructional efficiency of several instructional designs which enabled inferring that the efficiency of instruction or individual in the teaching process cannot be considered separately from the Cognitive Load Theory. One of the instructions that proved to be very effective in mastering chemical concepts is the instruction based on the Triplet model. Namely, using combined measures of students' success, it was found that this instruction increased student performance and reduced amount of invested mental effort.

Conclusions and Implications

The results of the research confirmed the expectations of the theoretical background that is, the need to include parameters related to the Cognitive Load Theory in efficiency evaluation. Instructional efficiency represents an important area of science education research and therefore, research based on the improvement of the methods and techniques of its evaluation is highly requisite.

In addition to the described results, further research should be focused on the application of the eye tracking technique as a very powerful tool which, in addition to the described benefits, also provides very important information on students' misconceptions. Besides, tested parameters should also include information on students' motivation as an important indicator of students' success.

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STUDENTS' ABILITIES OF READING IMAGES IN GENERAL CHEMISTRY: THE CASE OF REALISTIC, CONVENTIONAL AND HYBRID IMAGES

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Abstract

This research deals with students' abilities to read chemistry textbook images about dispersed systems. Secondary school students were included as the research participants, and their abilities to propose the titles of the realistic, conventional, and hybrid textbook images about dispersed systems, were analyzed. Additionally, their written interpretations about images contents were also analyzed. The collected data provided information about students' misunderstandings about dispersed systems. These misunderstandings, some of which are the original outcome of this research, provided the significant results. In addition, it was found that students had the most difficulties with reading realistic textbook images. Namely, they relied on what they literally saw on the realistic image (i.e. photography) without providing proper connection with chemical contents about dispersed systems.
Keywords: *visual representations, reading images, images types, general chemistry*.

Introduction

The visualizations play an important role in both science and science education. According to Gilbert (2010), visualizations, or more precisely visual representations exist in two different forms: internal and external. Internal visual representations (IRs) enable students to retrieve information from long term memory to solve problems, make decisions, etc. (Rapp & Kurby, 2008). Namely, IRs are structures in the memory (Zhang, 1997) that can be defined as mental outcome of visual display of an object or event (Rapp & Kurby, 2008). On the other hand, these objects, physical symbols, and dimensions that exist in our environment are external visual representations (ERs) (Zhang, 1997). ERs could be seen with the naked eye (Uttal & O'Doherty, 2008) and they provide the opportunity to us to internally think about abstract phenomena (Eilam & Poyas, 2010). Certainly, in chemistry education, students are faced with many abstract concepts. Henceforth, there are lots of possibilities for the application of various ERs, such as pie, line, or bar graphs, maps, molecular models, drawings, and photographs.

In this research one particular type of ERs, the textbook images, were of special interest. In the science education literature, many researchers conducted autonomous analysis of the images presented in the textbooks. For example, Dimopoulos, Koulaidis, and Sklaventi (2003) noted the classification of images by type and function. Regarding their type, images were characterized as realistic, conventional and hybrid. The realistic images represent reality in accordance with the human optical perception (e.g. drawings and photographs). Conventional images represent reality in a codified way, and they are constructed observing the techno-scientific conventions (e.g. graphs, maps, two-dimensional representations of molecular models). They are important for a scientific writing. At the end, hybrid images are combinations of elements from both realistic and conventional images.

Apart from the autonomous analysis of the textbook images, there are studies that were conducted in order to investigate students' ability to "read" images. Colin, Chauvet, and Viennot (2002) investigated students' difficulties in reading images in optic, as well as teachers' awareness of those difficulties. For the purpose of the study, they used textbook images along with the corresponding text elements. In some studies, the authors looked at textbook images in order to design own images particularly for the research. Ametller and Pintó (2002) developed theoretical semiotic framework in order to investigate secondary school students' interpretations of images about energy. These authors found that specific features of science images can cause difficulties for students while reading images, for example, the polysemic use of the arrows.

The present research focused on secondary school students' abilities to read images, analyzing two aspects: (i) proposition of the image title, and (ii) interpretation of the image content. In order to verify how usage of image can help chemistry learning in classroom, it was decided to use textbook images. Therefore, the following research tasks were defined:

(1) Analyze students' abilities to propose the title for the set of realistic, conventional, and hybrid textbook images.
(2) Analyze students' abilities to interpret the content of the realistic, conventional, and hybrid textbook images.
(3) Analyze students' misunderstanding while reading images.

Research Methodology

Study Participants

103 students (37 males, 63 females, and 3 unknown) from four classes of one grammar school from Novi Sad, Republic of Serbia, participated in this research. All of the students were enrolled in the first grade of grammar school and were 15-16 years old. Students were taught by the same chemistry teacher who holds a Master's degree. According to the evaluation, at the end of the first semester of the first year, 52% of students had excellent achievement in general chemistry, 39% had very good achievement, 7% had good achievement, and 2% had satisfactory achievement.

Context of the Study and Study Instrument

The research was conducted in the second semester of the first grade of grammar school in the 2017/2018 school year. For the purpose of the research, one teaching theme from general chemistry was chosen: “Dispersed systems”. In order to examine students’ abilities to read images in a chosen theme, it was decided to use textbook images. The recommended and one of the most used textbooks (“General Chemistry 1: Textbook for first grade of secondary school”) was chosen (Nedeljković, 2016). It was seen that selected theme includes 18 images in total, of which 8 realistic, 2 conventional, and 8 hybrid. In the process of choosing images for examination, were included: one full professor and two assistant professors in the field of Chemistry teaching, and one master student who were profiled to be chemistry teachers. Henceforth, 2 realistic, 2 conventional and 2 hybrid images were included in the knowledge test. All images included in the knowledge test were printed in black-and-white. However, the researcher presented images in original color, one by one, using computer and video projector. This ensured that students could see the content of image more clearly. The knowledge test was conducted on one school class (45 minutes) in May 2018, and students were required to propose the title for each of six images, and then to interpret the content of the image. By that, two types of data were collected: proposed titles of images, and written interpretations of contents of realistic, conventional, and hybrid images.

Data Analysis

The collected data were analyzed qualitatively. Firstly, two researchers analyzed together students’ written answers for each image. Then they developed a table for each image with several categories of proposed titles. Along with each title category, the number of students and corresponding percentages were included in the table. Since six images were included in the knowledge test, six tables were developed. After that, other three researchers carefully analyzed developed tables and each disagreement was solved through the discussion. Since several title categories of images indicated the presence of students’ misunderstandings of observed theme (“Dispersed systems”), the researchers looked into their written interpretations of images contents in order to collect more specific information about such misunderstandings.

Research Results

The first realistic image included in the knowledge test presented *The blue color of the sky as a result of Tyndall's effect.* From the total number of research participants, 19.4% were able to recognize that this realistic image has relation with Tyndall's effect. However, only 7.8% of students could interpret the content of the image in the sense of Tyndall's effect. For example, one student wrote: “Sunlight is scattering on particles in a colloid where a bright spot is on each one, and we see blue light scattered”. In the next category of proposed titles for this image belonged students who observed *Solar radiation*; *Reflection of sunlight*; or *Luminosity.* This category of proposed titles could be acceptable because Tyndall’s effect is related with sunlight. However, when students’ interpretations were analyzed, it was obvious that their proposals of image titles were reflection of what they literally saw on the realistic image. The same could be said for the relatively large group of students who proposed the titles: *Sun in the sky*; *Sun and clouds*; *Cloudiness*. The third group of students proposed the title: *Air as a dispersed system*. To this group belonged the students who proposed the title: *Coarse dispersion*. They believed that air is coarse dispersion where dispersed phase particles are bigger than 100 nm and could often be seen by naked eye. By that, we identified first misunderstanding within our study participants.

The original title of the second conventional image was *Solubility curves of various ionic (solid) substances.* The title that fully matches the one from the textbook was proposed by only one student. Six students proposed very similar titles (*Solubility curves of ionic substances* or *Solubility curves*). However, more than half of the total number of students suggested the correct titles for this conventional image, such as: *A graph of temperature dependence of solubility*; *The influence of temperature on the solubility*; *The solubility of the compounds in 100 g of water at the given temperature*. It was pleased to find that many students have developed crucial skills to deal with visual data presented in the form of graphs, as students will need such skills outside of classroom in everyday life. It is interesting to note that some students mixed this graphic display with a chemical reaction rate graph and with a graph showing the changes in energy in chemical reactions. Also, the small number of students believed that presented conventional image shows chemical equilibrium graph by not observing the fact that the included salts are strong electrolytes that are completely dissociated into ions in aqueous solution.

The title of one hybrid image taken from chemistry textbooks for the first grade of high school is the *Illustrative representation of dissolution of sodium chloride in water*. None of the students proposed a title that would completely fit with the one from the chemistry textbook, while one student proposed a very similar title: *Representation of dissolution of sodium chloride in water*. The most of the students suggested the title *Dissolution of sodium chloride in water* (or just *Dissolution of sodium chloride*, or *Dissolution of salt in water*). Some of the students used the term "dissociation" instead of "dissolution", which is also acceptable. One group of students focused their attention on a separated realistic element (magnifying glass) and on a conventional element (a model of the sodium-chloride structure). These students listed titles such as: *NaCl under the magnifying glass*; *Table salt under the magnifying glass*; *Representation of sodium chloride as a soluble substance under the magnifying glass*. It can be assumed that these students thought that the particles of sodium chloride can really be viewed under the magnifying glass. This was confirmed by students' interpretations of this image: "The magnifying glass may show a detailed dissolution of sodium chloride". Or, "A bowl is placed under the magnifying glass to facilitate the study of the obtained solution". However, one student wrote: "The substance from the image is dissolved into positive sodium ions and negative chlorine ions that are observed under magnifying glass which I believe is not possible!" Another misunderstanding appeared within the group of students who proposed the titles like *Enlarged molecules of sodium chloride*; *Molecules under the magnifying glass.* These students showed a misconception believing that sodium chloride exists in the form of molecules in a solution. Also, some students believed that there are molecules or atoms of sodium and chlorine in the solution. It is interesting to mention that three students proposed the title *Infusion*, knowing the use of 0.9% solution of sodium chloride in water in medicine.

Conclusions and Implications

In this research, the secondary school students' abilities to propose the titles of images and to interpret their content, were examined. All examined images were taken from the chemistry textbook and belonged to the one of three basic types of images: realistic, conventional and hybrid. The results showed that secondary school students have developed the ability to read images at a satisfactory level. It was found that the students had the most difficulties to read realistic images as they can often be confusing (metaphorical), decorative and without a clear attachment to the observed chemical contents. As far as conventional and hybrid images were concerned, there appeared significant results. The students were well acquainted with the interpretation of graphs and other conventional visual representations. Nevertheless, there were students who showed misunderstandings, some of which had already been recorded in the literature, and some were the original outcome of this research.

As a further direction of the research, combined application of images and multiple-tier tests could be used. In this way, the misconceptions could be more precisely identified. Additionally, the students' abilities to read realistic, conventional and hybrid images could be examined in other teaching themes from inorganic, organic chemistry, or biochemistry.

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ENGINEERING PEDAGOGY SCIENCE AS THE CONTEMPORARY BASIS FOR EFFECTIVE TEACHING OF SCIENCE, TECHNOLOGY AND ENGINEERING

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Abstract

This study is introducing the basic principles of Engineering Pedagogy Science for effective design, teaching and learning of science, technology and engineering. The basic didactical models are introduced for contemporary design of effective teaching and learning. A quadruple instruction model of Engineering Pedagogy Science is proposed, integrating the principles of Behaviourism, Cognitivism, Social Constructivism and Humanism on the basis of didactic model of Engineering Pedagogy Science.
Keywords: *didactical model, effective teaching of STE, engineering pedagogy, educational design, quadruple instruction model*.

Introduction

Engineering Pedagogy Science is a young interdisciplinary branch of pedagogical science that gives an overview of specific problems that arise in teaching STE (Science, Technology, and Engineering) subjects and helps to acquire necessary tools and skills to teach these subjects efficiently and competently. Scientific ideas of Engineering Pedagogy are primarily targeted for STE practitioners: engineers, doctoral students, knowledge workers, teachers and trainers who teach at upper secondary schools, vocational training institutions, and universities. The basic knowledge of Engineering Pedagogy Science, including STE didactics, enables to design teaching effectively, flexibly and taking account of the learning situation, so that poor teaching becomes better and good teaching - excellent, thus supporting effectual learning with deep understanding.

Psycho-Didactics and Engineering Pedagogy Science

Psycho-didactics is a multidisciplinary new field that combines the principles of psychology and didactics and creates the basis for effective teaching ensuring individualized education. The scientific ideas of psycho-didactics are one of the most important foundations of Engineering Pedagogy and STE didactics. The aim of psycho-didactics is to support the emotional, intellectual and ethical development of learners' personality and to develop the importance of values in the process of learning. Teaching critical thinking and supporting metacognition are also of great importance.

If the main issues of didactics were to define "*what to teach?*", "*how to teach*?", and "*why to teach?*" psychology adds "*who teaches*?", "*who is taught*?" and "*where is it taught*?". Expanding the main issues of didactics through the definition of supportive learning environment and the psychoanalysis of students and teacher, it should be emphasized that both - the learner's individual differences and preliminary knowledge, and the professionalism and competency of a teacher are of great importance in activating the process of cognitive learning in teaching and learning STE.

From Didactic Triangle to Didactic Pentagram

Didactic models ensure the design and analysis of effective teaching, and reflection on the educational process with the aim of improving teaching and learning, and perfecting the scholarship of teaching and learning (SoTL). For effective teaching STE a didactic pentagram of Engineering Pedagogy Science has been designed by the author of the present article taking account of the ideas of Uljens (1997), see Figure 1.

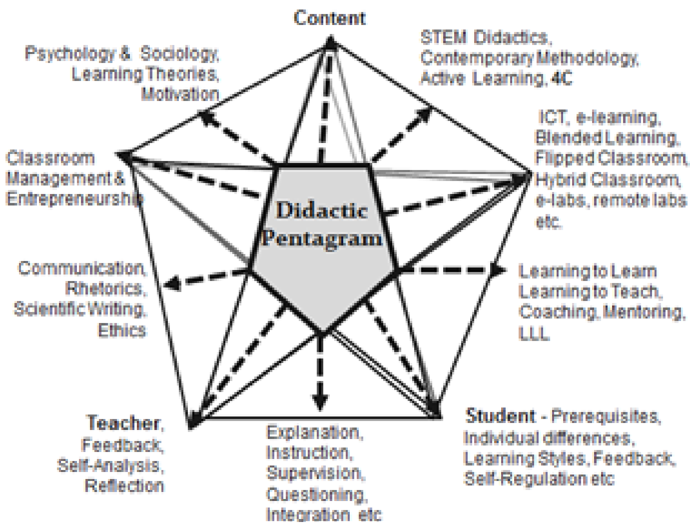

Figure 1. Didactic pentagram of engineering pedagogy science.

The didactic pentagram of Engineering Pedagogy Science is designed of different supportive didactic triangles placed on top of each other, built on the classic didactic triangle (teacher-students-content and continuous feedback between them). All the lines, arrows and pentagram sides relate on different aspects of effective teaching and learning STE.

The Didactic Model of Engineering Pedagogy Science

The didactic model of Engineering Pedagogy Science that has been developed by the author of the present article taking account of the principles of the Klagenfurt School of Engineering Pedagogy (Melezinek 1999), is presented in Figure 2 following the didactic questions below (Rüütmann 2019):

- *Why we teach*? – Is there any need for this course? Set clear and precise goals and relevant learning outcomes. By achieving our teaching goals, we create conditions and opportunities for our students to achieve their learning outcomes. For goal setting use didactic models (e.g. Bloom’s taxonomy (Anderson et al. 2001), Feisel-Schmitz’s taxonomy (Crawley et al. 2014), Hmelo-Silver’s PBL taxonomy (Hmelo-Silver 2004) etc.) and take account of three types of learning: cognitive, psychomotor and value domains. (Crawley et al. 2014);
- *Whom we teach?* – Analyse your target group, take account of their individual differences, learning styles, prior knowledge and how they learn (psycho-structure). Check whether the goals you have set are appropriate for your students' prior knowledge;
- *What we teach?* – Select only the most important content taking account of the goals and students’ prior knowledge, create logical structure. The time as a resource should be taken account of in order to create a balance between the scope and complexity of the content selected for learning. Align the content with the goals and students’ prior knowledge, compile assignments and e-learning materials, simulations, videos etc.;
- *With what and where we teach?* – Select relevant facilities and technology (socio-structure); create a supportive, positive learning environment. Select suitable new and classical teaching technology, media, laboratory equipment, online platform for e-learning etc. Align teaching technology and facilities with the content, students’ prior knowledge and learning outcomes;
- *How we teach?* – Select and analyse suitable teaching models, methods, strategies, ways of communication, set the ratio between individual and group work etc. Analyse if the selected teaching models, methods and strategies are relevant to the teaching technology, content, students’ prior knowledge – do they support critical thinking and reaching the learning outcomes;
- *How we assess and give feedback?* – Select relevant assessment and feedback methods that are suitable for the learning outcomes, content, take account of specifics of selected teaching methodology and teaching technology and analyse students’ critical thinking. How to ask and give feedback with the aim of supporting and improving teaching and learning?
- *How to improve the process of teaching and learning?* Analyse and reflect on the process of teaching and learning. Are the goals and learning outcomes, students’ prerequisites, selected content, technology, and assessment methods effective and efficient? Ask students and colleagues for feedback. If necessary, make changes to improve the quality of teaching and learning. Upgrade your teaching skills and teach students how to learn with deep understanding.

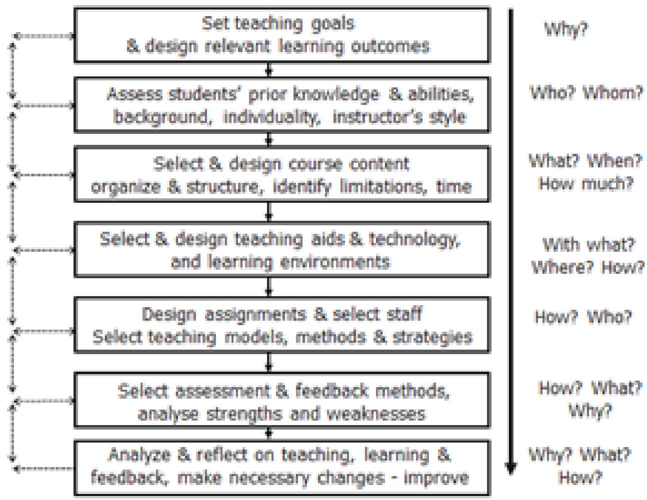

Figure 2. The didactic model of engineering pedagogy science.

Thus effective teaching of STE is influenced by a number of variables:

- Instructional objectives (O);
- Students' psycho-structure, prior knowledge and individual differences (P);
- Course content (C);
- Teaching technology and socio-structure (T);
- Teaching models and methodology (M);
- Assessment and feedback methods (A);
- Reflection and analysis of teaching and learning (R).

In Engineering Pedagogy Science teaching method is a function of different influential factors: M = f (O, P, C, T, A, R). If one of the variables will change, the methodology has to be changed. (Melezinek 1999).

There are always three types of learning: cognitive (knowledge), psychomotor (skills) and affective (values) being integrated in teaching STE.

Design of a Quadruple Instruction Model of Engineering Pedagogy Science

This study proposes a comprehensive quadruple instructional model of Engineering Pedagogy that has been designed on the basis of the didactic model of Engineering Pedagogy Science (Figure 2) and integration of four basic learning theories: Behaviourism, Cognitivism, Social Constructivism and Humanism (see Figure 3).

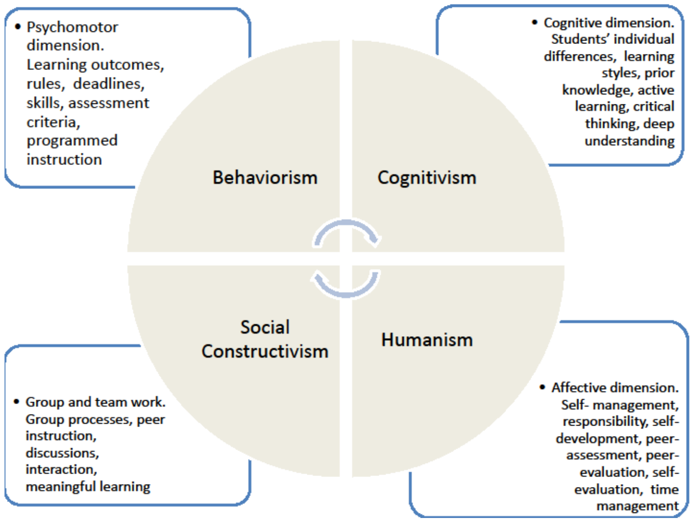

Figure 3. Integration of four basic learning theories.

Behaviourism supports the psychomotor dimension (acquisition of skills) in teaching STE. Behaviourism mainly contributes for the students' level - beginners. Behaviourism contributes for design of learning goals and learning outcomes, develops requirements, rules (including safety regulations), deadlines, and verifiability of results, takes account of differentiation, teaches to solve STEM problems, supports practicing, repeating, and implementation. Assessment is carried out according to assessment criteria with tests and exams. Teaching methodology of Behaviourism is: lectures, laboratory works, demonstrations, practicing, questioning etc. Teaching model is deductive teaching. Role of a teacher is manager; role of a student is to act according to the plan delivered by the manager.

Cognitivism supports the cognitive dimension (acquisition of knowledge). Constructivism is one construct of cognitivism. Cognitivism mainly contributes for the level of intermediate students. Cognitivism takes account of students' individual differences, learning styles, prior knowledge, and activity, integration, learning with comprehension, critical thinking, and chain of perception-knowledge-thinking. Cognitivism contributes for teaching methodology and strategies like: active learning, interactive lessons, concept maps, visualisation, integration, PBL, studio learning etc. Multiple choice tests are used. Teaching model is inductive teaching. Role of a teacher is supervisor, role of a student - explorer.

Social Constructivism supports cooperation and collaboration, and contributes with group and team work, peer instruction, imitation, analysis of group processes, discussions and interaction, knowledge exchange and experiential learning, meaningful learning with deep understanding and comprehension, supervision. Role of a teacher is facilitator, role of a student – team member. The process of a team work is assessed by self- and peer-assessment, feedback is used.

Humanism supports affective dimension (values and attitudes) contributing mainly for the advanced level of students. Humanism contributes with self-management, responsibility, self-development, peer-assessment, peer-evaluation, peer-instruction, time-management, and self-regulation, discussions. Assessment is carried out on the basis of a scale or check-list and on the basis of feedback. Role of a teacher is mentor, role of a student – designer. Mentoring and coaching is widely used.

In Figure 4 a comprehensive quadruple instructional model of Engineering Pedagogy is presented.

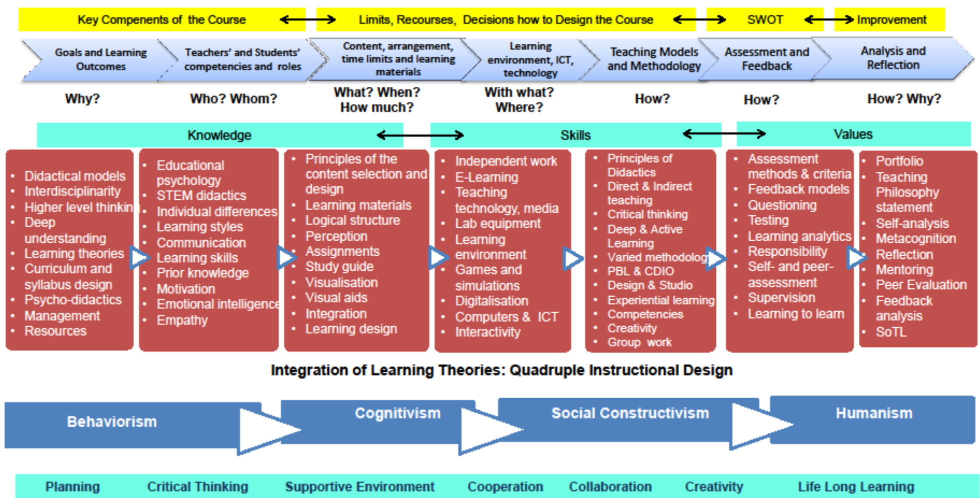

Figure 4. A quadruple instruction model of engineering pedagogy science.

In the process of development of a quadruple instructional model of Engineering Pedagogy Science, the Didactic Model of Engineering Pedagogy Science has been integrated with the principles of four basic learning theories. The presented model is an effective tool for a productive instructional design in the field of STE. The quadruple instructional model of Engineering Pedagogy Science has been implemented in the curriculum and instructional design of the Technical Teacher Master programme at Estonian Centre for Engineering Pedagogy. Feedback from the students, faculty and stakeholders has been positive.

Conclusions

In the process of planning STE teaching, the fact that effective teaching is a unique art should be considered. The actual process of learning develops in a real world environment. Thus, depending on learning goals and outcomes, students' prior knowledge and individual differences, learning skills, motivation, course content, methodology, technology effective lesson could be developed according to the real learning situation. Therefore, knowledge of STE didactics helps teachers and faculty to make scientifically informed decisions and relevant changes to support students' learning with deep understanding. The proposed quadruple instruction model of Engineering Pedagogy Science enables the design of an effective STE teaching.

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TEACHING SYSTEMS THAT CAN MIMIC DIFFERENT TEACHING-LEARNING ENVIRONMENTS

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Abstract

Conventional learning guidance systems are typically automated machines for creating teaching materials: quizzes, exercises, examinations etc. In the future, systems will also offer ease of use, attention to sociality, ability to adapt to the pupil's needs and skill levels, and time savings.
Ease-of-use and adaptation can be sought using systems based on Artificial Intelligence (AI). Chatbots would save teachers time by talking with students about their problems automatically. The virtual classroom would release people from the physical state and offer the opportunity to play with different roles. For the teaching of physics, the virtual classroom provides an opportunity to try out things that are not practically possible. AI could enable automatically identify students' strengths and weaknesses and utilize them. On the other hand, AI also could allow pupils to gain strength through peer learning by bringing students of the same level from all over the world to discuss their own views and could automatically filter out sub-standard and clearly false answers. AI can also be capable of automatically creating tailor-made materials based on student-level learning using deep learning. Finally, AI can also be used to treat pupils' reviews to a large extent. In this research we will evaluate how well new technology powered by AI could respond to the demands of different teaching-learning environments.
We will present a learning system that is in use and discuss its differences between opportunities of Artificial Intelligence (AI) can support different teaching-learning environments and discuss little how AI could support different learning styles.
Keywords: *automatic teaching machine, artificial intelligence, student centric learning, learning environment, learning style.*

Introduction

Being bored has been a fruitful source of creativity. Before digital age with mobile phones, tablets, computers and Internet people had to crab a pen and draw and write or read some book. This was essential to the development of linguistic as well as concentration and logical thinking skills. All of this can be threatened by nowadays fast-food culture for brains offered by our new gadgets which are more often used by their users for easy relaxation than for development of their skills. One challenge is to create interactive learning systems that support creativity. Other challenge is to make people actually use them instead of using social media, playing addictive online games, watching streaming videos etc.

Nowadays learning systems are demanded good usability, social aspect, ability to adapt learners' needs and skill levels and time-effectiveness. Artificial intelligence offers many solutions. Chatbots are more or less clumsily able to chat with people and they could be programmed to have intellectual discussions adapted to the people's own needs, intellectual level and stage of development. Virtual classrooms free us from physical phase, people can play with different roles and test things that are not possible in a real world. Artificial Intelligence (AI) can detect people strengths and weaknesses, support peer learning and bring automatically tailored materials supporting deep learning.

Traditional Exercise Creation System

The system presented in this section has features similar to Maple T.A. (Maple, 2019). This means that the application creates parametrized exercises, which have the benefit of ensuring that students never get exercises with the same starting values. Therefore, the system eliminates the dilemma of running the exact same exercises year after year.

Any exercise is first written in the area called "Tehtävä"—in this case "Population of China." The population of China in the year 2012 and growth rate are constants here, but they could have been given as parameter values too. The year corresponding to the population is given as a parameter that is marked as @v_1@. The solution is given in the form x=1344130000*1.0047^(v_1-2012) to the area called "Derivoitava/Integroitava/Vastaus: (ilman @-merkkejä)." The keywords are population growth, exponential, basic and recap. Parameter limits are chosen in the following way: placed at the top or bottom of a page. Figure 2 shows a screen replica of the straightforward interface.

Figure 1. Draft illustration of an exercise editor.

Adding exercises is a relatively simple task for the average instructor. The interface is straightforward, so it is also easy for students to learn, though it is still something new that each student must learn. Currently, the system has 403 different exercise types, from algebra and statistics to partial differential equations. After an exercise is written into the editor, it is added to the database using PHP-code (PHP, 2019). Visualisation is done using a LaTeX2HTML-program called MathJax (MatJax, 2019), which makes use of formulas to improve the appearance of the visualization in the browser's online interface.

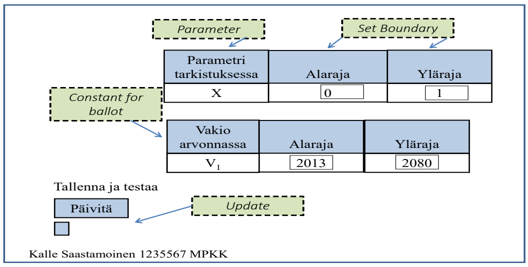

Figure 2. Adding parameters.

Benefits of this system are:

- It offers studying environment in which student has the possibility of recognizing and improving his/her own areas of weakness in mathematics.
- Teachers can concentrate on teaching those areas in which students do not excel in their exercises.
- In general, it is possible to optimally concentrate limited teaching capacities.
- It offers an automated exercise generator.
- It offers parameterized exercises.
- Students *always* get different exercises to solve.
- The system automatically checks exercises and gives immediate feedback.
- The teacher can remotely surveil the exercises through the Internet and see in real-time how students are evolving within the given exercises.

Students' Different Approaches Towards Learning vs. Teaching-Learning Environment

In research article (Parpala, 2013) learning styles were divided to three classes that were 1) Deep approach 2) Organized studying 3) Surface approach and factors measuring experiences of the teaching–learning environments to six classes that were 1) Teaching for understanding 2) Alignment 3) Staff enthusiasm and support 4) Interest and relevance 5) Constructive feedback 6) Support from other students. Table 3 shows the ESEM (Exploratory Structural Equation Modeling) estimated correlations between students' scores on the six factors of experiences of the teaching–learning environment and students' scores on the three factors of the approaches to learning and studying inventory (Parpala, 2013).

Table 1. Intercorrelations between perceptions of the teaching–learning environment factors and the approaches to learning factors (*p*<.001 and *n*=2509) (Parpala, 2013).

Factor	Teaching for understanding	Alignment	Staff enthu-siasm and support	Interest and rele-vance	Con-structive feedback	Support from other students
Deep approach	.43	.16	.22	.32	.25	.11
Organized studying	.18	.24	.12	.36	.23	.22
Surface approach	-.44	-.51	-.22	-.47	-.14	-.23

Discussion

From the table 1 we see that different learning styles affect how students interpret their teaching-learning environment from the table 2 we see how AI and traditional teaching-learning environments mimic different teaching-learning environments. While traditional teaching support system mimic mainly only partially or not at all different environments AI based systems at least have potential to mimic totally these environments presented. The other question is how well these systems could support creativity. This we can study through definition of evolutionary creative (Shneiderman, 1999) that is a process with four phases 1) Collect: learn from previous works stored in libraries, the Web, etc.; 2) Relate: consult with peers and mentors at early, middle, and late stages; 3) Create: explore, compose, evaluate possible solutions; and 4) Donate: disseminate the results and contribute to the libraries. These seem to be demanding still for AI to handle without any human intervention.

Table 2. Conventional teaching support systems vs. AI supported teaching environment in the view of teaching-learning environment.

System	Teaching for understanding	Alignment	Staff enthu-siasm and support	Interest and rele-vance	Con-structive feedback	Support from other students
AI	YES	YES	YES	YES	YES	YES
Conven-tional	PARTIAL	YES	PARTIAL	PARTIAL	NO	NO

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THE STUDENTS' OPINIONS TOWARD INTERACTIVE LECTURES

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Abstract

The research purpose was to create and test the interactive lectures for lower secondary schools based on the characteristics of interactive ICT-supported education. First verification was carried out in the December 2018 on specialized school-board information technologies in Karaganda (Kazakhstan). The sample included two of eighth grade classes chosen, in total 26 respondents participated. The students' opinions toward interactive lectures in this study were tested using simple questionnaire survey. The results showed that more than 70 % of the students enjoy working in an interactive environment and this positively affects their opinions towards the subject.
Keywords*: interactive lecture, secondary school, students' opinions.*

Introduction

Despite the fact that pedagogic theory has changed significantly in the last decades, it resulted in a shift away from traditional lecture to more interactive teaching strategies (AAAS, 2011). Moreover, the variety of learning styles and temperaments of students (introverts and extroverts) suggest that an assortment of interactive learning strategies must be employed to effectively reach all students (Murphy et al., 2004).

An interactive approach may range from questions during the lecture and group work up to more complex activities that involve hands-on experience with material. These strategies are consistently linked to the improved measures of learning (e.g., Connell et al., 2015; Anderson et al., 2011), and it is widely acknowledged that active learning strategies will better serve the diverse learning patterns of the student population. Interactive lecture implies active involvement and participation by the audience so that students are no longer passive in the teaching process. Learners can communicate with the teacher, give him/her feedback, and can thus actively influence the teaching (Vališová & Kasíková, 2007). Because of this, their interest can be improved and their intellectual abilities stimulated (Petruţa, 2013). The students are allowed to use their personal devices such as mobile phones, tablets and laptops that allow for similar interactive lecture styles using these technologies (Sadykov & Čtrnáctová, 2018).

Whereas little has been written about the benefits and application of interactive lecturing for schoolteachers.

Schwerdt and Wuppermann (2011) examined whether the time that teachers spend on lecturing style teaching can influence the performance of U.S. students. The study showed that students benefit when their teachers spend more time on lecturing style teaching. Traykov and Galcheva (2017) stated that students from 9th grade at the "Dr. Petar Beron" School of Mathematics in Varna enjoy working in an interactive environment (69%) and this positively affects their attitude towards the tasks.

Addressing the issue of efficient use of interactive lecture lies not only in analysis of learning outcomes through assessments, but also in feedback provided by students (Hake, 1998; Sokoloff & Thornton, 1997). Therefore, *the aim* was to create and test interactive chemistry lectures for lower secondary schools based on the characteristics of interactive, ICT-connected education.

Research Methodology

First verification was carried out in the December 2018 on specialized school-board information technologies in Karaganda (Kazakhstan). The main objective of the educational program of the school is the development of individual, creative and research abilities of students in the active study of the use of information and communication technologies. This school services 292 students in grades 7–9 (2 classes in Russian language and 2 classes in Kazakh language are taught in each year). The specialized IT school board is located in a large town (Karaganda), but despite this, the participating students came from rural as well as urban areas, and there was no selection as regards their intellectual or achievement level for them to participate.

The sample included two of eighth grade classes chosen, in total 26 respondents participated (11 female adolescent and 15 male adolescent). One class of eighth grade consisted of 6 female adolescent and 8 male adolescent, another class of eighth grade consisted of 5 female adolescent and 7 male adolescent, which entailed a total of 4 hours of experimental action per student. Their age ranged from 14 to 15 years old.

It was aimed to study the students ‘opinions on the basis of 2 interactive lectures (classification of chemical reactions, factors influencing the rate of chemical reaction). The questionnaire used in this research consisted of six closed-ended questions:
1. Do you like interactive lecture with the use of computer for presentation?
2. Do you think that interactive lectures are more interesting than the traditional lesson?
3. Was explanation in the interactive lecture clear, and therefore, I understood the topic well?
4. Do you think that the interactive lecture had too much information, diagrams and images, so I found it difficult?
5. Would you like if interactive lecture like this could be carried out more often?
6. Were you interested in solving the tasks using a mobile phone or a tablet?

A three level rating scale from 1 to 3 as follows: 1-Disagree, 2-No opinion, 3-Agree was selected as being the most appropriate to measure participants’ opinions.

Research Results

The interactive lectures on the topics “Classification of chemical reactions” and “Factors influencing the rate of chemical reaction” were posted on the educational site: http://interactive-chemistry.ru. The lessons from interactive course consisted of text, pictures, animation, questions and tasks in interactive exercises, which are available in each stage of the lesson.

The figure 1 illustrates overall students’ opinions toward interactive lectures. It shows separate answers for all six questions. The students' answers to the question were as follows:

More than three-quarters of the students (76%) like interactive lecture with the use of computer presentation and understand the topic well, while approximately one in five of the students (23%) say they have “no opinion” in this area.

Similarly, 73 % of the students believe that interactive lectures are more interesting than the traditional lesson and would like the interactive lecture to be carried out more often, while less than (27%) say they have “no opinion” in this area. Only 8 % of the students rate themselves as “disagree”.

It is interesting to note, more than half of the students (54 %) do not think that the interactive lecture had too much information, diagrams, and images.

As a final point, it is not surprising that approximately 77 % of the students like using a mobile phone or a tablet while solving interactive tasks.

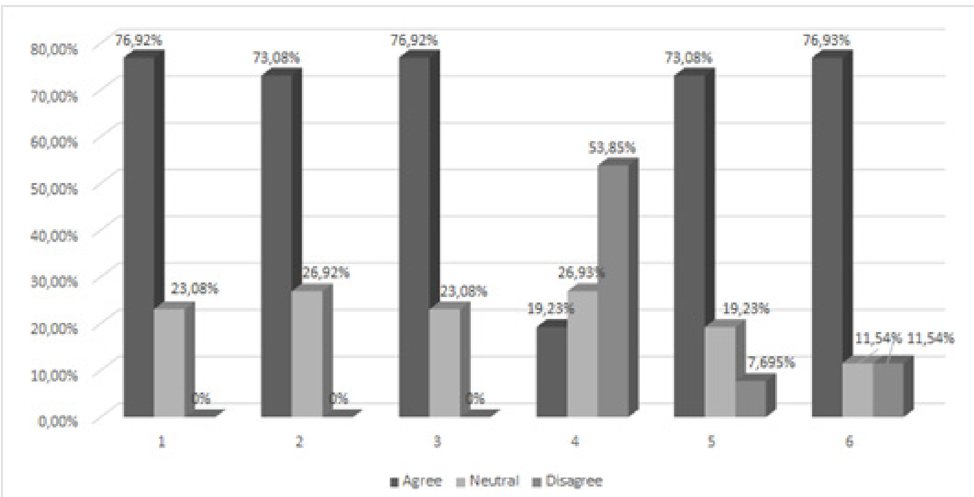

Figure 1. The overall students’ opinions toward interactive lectures.

Conclusions

Firstly, we developed and adapted interactive lectures for lower secondary schools, which could be used in various parts of chemistry lessons. Secondly, the students’ opinions toward interactive lectures in this study were tested using a simple questionnaire survey. First verification on school showed that more than 70 % of the students enjoy working with interactive lectures and this positively affects their opinions towards the subject. In the next part, we will therefore focus on verification of the use of interactive lectures in other schools in both Kazakhstan and the Czech Republic.

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INDIVIDUAL BEHAVIORS AS MOTIVATION, TASK COMMITMENT, AND LEADERSHIP EXHIBITED BY SCIENCE GIFTED STUDENTS AT SCIENCE GIFTED EDUCATION CENTER AND ITS IMPLICATIONS FOR DIFFERENTIATED INSTRUCTION

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Abstract

The research aimed to explore characteristics of individual behaviors as motivation, task commitment, and leadership exhibited by science gifted students at enrichment program in science gifted education center. Results showed that motivation was highest at introduction stage, but decreased as lessons progressed. Task commitment and leadership tended to increase from planning and conducting stages. Leadership was highest at discussion stage. Each student exhibited different sequences of behavioral characteristics along lesson stages. It was called for planning individually differentiated instructional strategies.
Keywords: *individual behavioral characteristics, science gifted students, student leadership, task commitment.*

Introduction

It is not easy to predict how future society will change. The global society is closely connected in complicated ways and is actively interacted with open-communication due to infinitely developing internet network and unlimitedly accessible information. Complex societies generate more unexpected phenomena and various problems, and people use knowledge to solve problems and create new values. Jack Andraka, when he was15-year-old as a high school student, had mastered hundreds of research papers and had conducted thousands of experiments to invent an early diagnostic kit for pancreatic cancer. In the future society, we will need more creative talents who can demonstrate competence, accept change, pioneer the future, grow infinitely, and propose new alternatives beyond the fixed framework.

Looking at past history, there were experts of each field in the process of changing and developing the times. As a result, society has developed and culture has been formed. For this reason, many countries are focusing on cultivating top-notch specialists and high-quality human resources. In order to lead advanced science and technology, countries are strengthening science gifted education with the aim of fostering high-quality human resources capable of producing creative knowledge in science and technology. In other words, science gifted education makes more efforts to educate students to demonstrate outstanding expertise of science and technology in future.

In science gifted education, we are interested in exploring the characteristics of scientists who have achieved excellent outcomes, and are more interested in teaching students to demonstrate the scientists' characteristics. It is reported that those who had made excellent productivity did not achieve only by high intellectual abilities of innate giftedness, but rather that they were provided with appropriate opportunities and conditions to perform and practice enough (Tennenbaum, 2003). Their distinguishing feature was the commitment and sacrifice that they were willing to make it pursuit of their creative productivity (Subotnik, Olszewski-Kubilius, & Worrell, 2011). From this perspective, exceptional expertise can be interpreted as a result of combining individual characteristics of motivation, task commitment, and leadership. It can be effective teaching strategies for science gifted students to experience such behavioral characteristics during science learning.

In previous research, motivation, willingness to succeed, concentration, and leadership were discussed as predictors of excellent scientific creativity (Trost & Sieglen, 1992, recited from Heller, 2007). Such predictors include motivation and abilities to solve problems, to desire to influence initiatives and leadership for the success, to search for more knowledge, and to perform concentration ability and persistence. Science gifted students enjoy the process of discussing with their peers of similar abilities and interests, and they are motivated through exchanges with mentor professionals (Whybra, 2000). Gifted students were found to have higher motivation and greater enthusiasm in the course of mutual support and mutual evaluation and recognition by their peers in the learning process (Fredricks, Alfeld, & Eccles, 2010). Therefore, it is necessary to find out how and when students exhibit behavioral characteristics of motivation, task commitment, and leadership.

This research aimed to explore individual behaviors exhibited by science gifted students during the enrichment program of biology at a science gifted education center in Korea. For this purpose, research questions are formulated as follows: First, how frequently distinct behavioral characteristics such as motivation, task commitment, and leadership are observed at different stages of science lessons. Second, how these behavioral characteristics are individually sequenced at various stages of science lessons. It is expected that the research results are useful for developing individually differentiated teaching strategies to strengthen such behavioral characteristics.

Research Methodology

Participants

Research participants were ten students of middle schools in the Busan metropolitan city in Korea who enrolled in enrichment program of biology at science gifted education center affiliated with a university in March 2018 and who were permitted to continue a scientist mentoring program in the following year of 2019 based on multiple faceted evaluations. At the beginning of program, the participants filled out a survey of personal preference in science teaching strategies and future profession (Table 1). Students prefer science teaching strategies that allow them to solve lesson topics through experiments, discuss about results, and give class presentation, and share ideas. On the other hand, students do not prefer teaching strategies that science teacher explains, and students listen only without understanding and reasoning and that take too much time to conduct experiments and projects.

Table 1. Demographic information of research participants and their preference in science teaching.

Id	Gender	Grade	Future job to hope	Most preferred science teaching strategies	Least preferred science teaching strategies
S1	Female	7th	Biologist	use experiments and videos	lecture theories and difficult contents
S2	Male	7th	Biotechnologist	explain science concepts	present contents without understanding
S3	Female	8th	Medical doctor	use videos, allowing student presentation	learn only with textbooks and worksheets
S4	Female	8th	Medical robotologist	solve lesson topic through experiments	teacher continues explanation only
S5	Male	7th	Nanobiotechnologist	discuss and share ideas	teacher does all in classroom
S6	Female	7th	Biotechnologist	use a lot of experiments	learn theories only
S7	Female	8th	Biotechnologist	play games about lesson topics	take too much time for experiments
S8	Male	7th	Biologist	no preference	take too much efforts for doing projects
S9	Female	7th	Profiler	no preference	no preference
S10	Male	7th	Microbiologist	share hypothesis and discussion	learn theories without experiments

Data Collection

Participants' individual behavioral characteristics exhibited during the enrichment program of biology were observed and recorded by four preservice biology teachers for 39 classroom hours of 13 lesson topics from April to July 2018. Four observers were instructed to record objectively, concretely, and in details about distinct behaviors exhibited by each student during lessons. The 13 lessons were mostly progressed by four stages: introduction, experiment planning, conducting, and discussing results. Records of observation were divided into four stages at the time of observing and recording. During data collection, observers focused on observing and recording individual behavioral characteristics as much as possible. However, there is a limitation in that distinct behavioral characteristics of all students are not uniformly observed.

Data Analysis

A framework to analyze data was developed from categorization of raw data. The characteristics of behaviors observed were classified into similar categories into motivation, task commitment, and leadership as Table 2. Raw data were analyzed by utilizing the framework. Inter-rater reliability was established by comparing, discussing and reaching agreement among three raters.

Table 2. A framework of behavioral characteristics for data analysis.

Categories	Subcategories of behavioral characteristics and examples
Motivation	(M1: intrinsic motivation: exhibited as individual level) to question by themselves for further curiosity; to listen and take notes carefully; to ask questions frequently; and others
	(M2: achievement motivation: exhibited during interacting with teacher and students) to participate in experiments; to answer teacher's questions for given tasks; to volunteer classroom presentation; and others
Task commitment	(TC1: persistence: exhibited as making efforts over time) to explain new and more ideas with scientific reasoning to perform experiments thoroughly; to seek for new data not given; present ideas visually and creatively; and others
	(TC2: proficiency: exhibited skills in manipulating experimental tools) to make accurate and detail observation; to manipulate tools in proficient and sophisticated ways; and others
	(TC3: passion/flow: displayed intensively absorbed behaviors) to share happiness and excitement about work with peers; to immerse activities not being aware of peers; and others
Leadership	(L1: leading group performance) to persuade peers and dominate with own ideas; to lead discussion; (negative) to insist own conclusions; and others
	(L2: supporting others' participation) to allocate roles to group members; to encourage and support peers; to explain ideas to group members' better understanding; to remind peers about each role and duty; and others
	(L3: focusing social problems) to propose solutions for societal problems; to emphasize societal duties; and others

Research Results

It was found that there were frequency differences in observed behavioral characteristics among 13 lessons along four lesson stages (Table 3). There were 349 observations with ranges between 46 (lesson: photosynthesis with MBL) and 11 (lesson: immunology and living organisms) and distributed at four lesson stages: 16.9% for introduction of topic, 27.5% for planning experiments, 26.7% for conducting experiments, and 28.9% for discussing results. Differences in frequency observed from 13 lessons were likely to occur due to various teaching strategies from experimental activity oriented to heavy explanation of lesson topics.

Table 3. Behavioral characteristics observed at 13 lesson topics along four lesson stages.

Lesson topics	Lesson stages									
	Introduce topics		Plan experi-ment		Conduct exp.		Discuss results		Total	
1. Photosynthesis experiments with MBL	4	(8.7)	21	(45.7)	10	(21.7)	11	(23.9)	46	(13.2)
2. Science inquiries and exper-iments	4	(19.0)	7	(33.3)	6	(28.6)	4	(19.0)	21	(6.0)
3. Research like Darwin and Finch	3	(12.5)	15	(62.5)	2	(8.3)	4	(16.7)	24	(6.9)
4. Structure and function of brain	3	(9.4)	13	(40.6)	2	(6.3)	14	(43.8)	32	(9.2)
5. Implant Brain	0	(0.0)	13	(32.5)	5	(12.5)	22	(55.0)	40	(11.5)
6. Chromosome and DNA in plant cells	1	(5.0)	7	(35.0)	8	(40.0)	4	(20.0)	20	(5.7)
7. Protozoa observation and its ecosystem	5	(19.2)	3	(11.5)	14	(53.8)	4	(15.4)	26	(7.4)
8. Immunology and living organisms	10	(90.9)	0	(0.0)	1	(9.1)	0	(0.0)	11	(3.2)
9. Diverse senses in human	11	(45.8)	6	(25.0)	0	(0.0)	7	(29.2)	24	(6.9)
10. Osmosis and protoplasm	2	(5.6)	7	(19.4)	15	(41.7)	12	(33.3)	36	(10.3)
11. The world of mysterious optical illusion	5	(25.0)	2	(10.0)	11	(55.0)	2	(10.0)	20	(5.7)
12. Stem cells and therapeutics	8	(47.1)	2	(11.8)	6	(35.3)	1	(5.9)	17	(4.9)
13. Investigating epidemics and science writing	3	(9.4)	0	(0.0)	13	(40.6)	16	(50.0)	32	(9.2)
Total	59	(16.9)	96	(27.5)	93	(26.7)	101	(28.9)	349	(100.0)

Relative percentages of motivation, task commitment, and leadership based on frequencies of behavioral characteristics were shown in Figure 1. At the lesson stage of introduction, motivation (78.5%) was mainly exhibited and task commitment (19.6%) also appeared while leadership (1.8%) was rarely observed. During the planning stage, task commitment (48.9%) was higher than other categories, while motivation (35.6%) was decreased and leadership (15.6%) was increased. During the conducting stage, task commitment (54.7%) was higher than other categories, while motivation (19.8%) was again decreased and leadership (25.5%) was further increased. At discussion stage, leadership (45.2%) was highest and task commitment (43.2%) was also high. In general, motivation was the highest at introduction stage, but decreased as the lessons progressed. On the other hand, task commitment and leadership tended to increase from planning and conducting stages. During discussion stage, leadership was the highest.

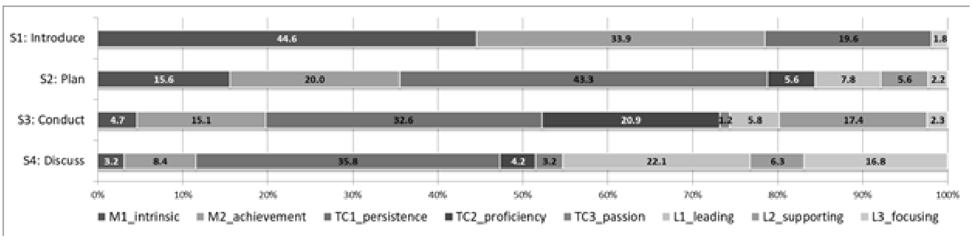

Figure 1. Behavioral characteristics observed at 13 lesson topics along four lesson stages.

Mean frequency of behavioral characteristics for each student appeared as 2.69 (0.99) at each lesson (Table 4). Ten participants showed ranges between 4.00 as highest and 1.54 as lowest frequency of behavioral characteristics at each lesson.

Table 4. Mean frequency of behavioral characteristics at each lesson for each participant.

Std ID	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	Av-er-age
Mean Fre-quency *SD*	3.00 1.78	2.46 1.98	2.92 1.66	1.54 1.13	2.23 1.24	3.31 2.06	1.92 1.04	2.23 1.30	3.23 1.54	4.00 2.27	2.69 0.99

Sequences of behavioral characteristics along four stages of science lessons were extracted. Among ten participants, most students showed distinct behavioral characteristics over one or two stages. However, six participants displayed certain specific sequences over three or four stages (Table 5). Student 1, who likes science teaching by doing experiments and watching videos, showed her sequences starting with leadership to explain additional ideas to lead peers (L1) at planning stage, and manipulating microscope skillfully to observe cells accurately (TC2), and observing repeatedly and recording precisely (TC1) at conducting stage, and finally taking photos of observation by cellular phone camera (TC2), sharing photos with peers to explain her own additional observation (L2), summarizing newly learned biology terms in notebooks by herself (M1), and asking teacher to make sure what she understood (TC1) at discussion stage. Student 2, who prefers science teaching by explaining science concepts, showed his sequences starting with leadership to explain how to establish variables to peers (L2), adding more variables from his own perspectives (TC1), and presenting his ideas to predict experimental results to class voluntarily (M2) at planning stage. At conducting stage, he encouraged peers to fill out worksheet and assist them (L2) and he initiated discussion (L1) and tried to encourage peers to complete worksheet (L2) at discussion stage.

Student 3, who likes class presentation, and student 6, who prefers doing experiments, exhibited similar sequences of motivation to answer teacher's questions (M2) at introduction and planning stages, and following task commitment (TC2, TC1) at conducting stage, and supporting peers (L2) or emphasizing social problems (L3) at discussion stage. Student 8 showed motivation (M2) at planning stage, and task commitment (TC1, TC2) at conducting stage, and finally became to absorb in his own results without being aware of peers (TC3) at discussion stage. Student 10, who likes discussion, started with motivation of curiosity in lesson topic at introduction stage (M1) and task commitment (TC2, TC1) till to immerse experiment without noticing teacher's comment (TC3), and motivation (M2, M1) at conducting stage, and task commitment (TC1) at discussion stage.

Table 5. Sequences of behavioral characteristics along four lesson stages.

Student ID	Lesson topic	Phases and behaviors				# of observed
		Introduce	Plan experiment	Conduct experiment	Discuss results	
S1	Osmosis and protoplasm		L1→	TC2→TC1→	TC2→L2→M1→TC1	7
S2	Photosynthesis w/ MBL		L1→TC1→ M2→	L2→	L1→L2	6
S3	Diverse senses in human	M2→	M2→	TC2→L2		4
S6	Brain structure and function	M2→	M2→	TC1→	L3	4
S8	Osmosis and protoplasm		M2→	TC1→TC2→	TC3	4
S10	Photosynthesis w/ MBL	M1→M1	→	TC2→TC1→TC3→	M2→M1→TC1→TC1	9

Conclusions and Implications

It is interpreted that science gifted students turn their motivation to task commitment by initiating experimental ideas and conducting experiments. Furthermore, leadership was interpreted to be exhibited more in class situations where group activities lead to cooperation, discussion, and agreement with peers. However, each student showed different sequences of motivation, task commitment, and leadership along lesson stages. Some students started with leadership at planning experiment stage and exhibited more at discussing results stage, while some students started with motivation and exhibited task commitment intensively at conducting experiment and discussing results stages. Such different sequences of individual behavioral characteristics along lesson stages called for individually customized and differentiated instructional strategies.

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DEVELOPMENT OF AN ASSESSMENT TOOL FOR POSITIVE EXPERIENCES ABOUT SCIENCE (PES)

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Abstract

This research aimed to develop an assessment tool for students' Positive Experiences about Science (PES). A preliminary version of PSE was developed through literature review, consisting of academic emotion, self-concept, learning motivation, career aspiration, and attitude in science. A pilot test was conducted with 198 students and a main test was then conducted with 1,841 students. The PES test found to have good validity and reliability. There were significant (p<.05) differences by students' grade, gender, and participation in science activities.
Keywords: *positive experiences about science (PES), science academic emotion, science-related self-concept, science-related motivation.*

Introduction

Traditionally, students' cognitive achievements have been considered as major goals in science teaching and learning in schools. However, affective aspects such as students' learning motivation, beliefs, and attitudes became an important educational goal due to the influence in students' career aspiration and academic professions in society as well as the quality of personal life (National Research Council, 2011). Although students in Korea have achieved higher cognitive achievements in science than international average in PISA and TIMSS, affective achievements in science have been the lowest among the participating countries (Choe, et al., 2013). Improvement of affective achievements in science became an urgent agenda in Korea.

When a national science curriculum in Korea was revised in 2015, the positive experiences about science (PES) became an important aspect as the 2015 revised national science curriculum is more competency–based (rather than subject domain-based) and more emphasizing student-driven activities and process-based (rather than outcome-based) assessments in schools (MOE, 2016). Characteristics of affective achievements can be a driving force that helps students lead self-directed, engage happily, and not give up easily even when faced with difficulties in science learning. In addition, students' emotional experiences such as enjoyment and interests in science learning situations can help them sustain reasonable and scientific attitudes in everyday life and career decision situations. Students' affective achievements in science are considered as important as cognitive achievements in Korea.

However, assessment tools and standards to evaluate students' affective achievements are still limited. It was needed to have more research on teaching and learning strategies and evaluation methods to enhance students' positive experiences about science. It was necessary to identify the students' affective characteristics influencing PES and indicators to evaluate students' affective achievements in science. Therefore, the aim of this research was to explore the components of students' positive experiences about science and develop and validate reliable assessment tools to evaluate students' affective achievements in science.

Research Methodology

Participants

Participants for the pilot research consisted of 198 students (95 female; 48.0%) including 53 4th, 43 6th, 39 8th and 63 10th graders. The main test to establish reliability and validity was administered to 1,841 students (892 female; 48.5%) who were sampled from 947 schools of elementary (grades 1-6), middle (grades 7-9), and high (grades 10-12) schools nationwide.

Table 1. Demographic information of research participants.

School level	Grade level	Pilot test			Main test		
		Male students	Female students	Total	Male students	Female students	Total
Elemen-tary	4th	29 (14.6)	24 (12.1)	53 (26.8)	212 (11.5)	184 (10.0)	386 (21.5)
	6th	25 (12.6)	18 (9.1)	43 (21.7)	202 (11.0)	196 (10.7)	399 (21.7)
Middle	8th	19 (9.6)	20 (10.1)	39 (19.6)	248 (13.5)	242 (13.1)	490 (26.6)
High	10th	30 (15.2)	33 (16.7)	63 (31.8)	287 (15.6)	269 (14.6)	556 (30.2)
	Total	103 (52.0)	95 (48.0)	198 (100.0)	949 (51.5)	892 (48.5)	1,841 (100.0)

Test Items Generation

A review of the literature suggested that characteristics of positive experiences about science (PES) include five components of science academic emotion, science related self-concept, science learning motivation, science related career aspiration, and science related attitude. After two times of Delphi survey with science educators, PES assessment tool was established with 35 items of a four-point Likert scale of potential responses, very often = 4 (very positive), often = 3 (positive), sometimes = 2 (negative), and never = 1 (very negative).

Data Collection and Analysis

Data were collected during October 2016 by online survey. Respondents to instrument took about ten minutes in average to complete the tool. Raw data were gathered in excel program and statistical analysis was performed with SPSS 18.0 for descriptive statistics, reliability test, confirmatory factor analysis, one-way ANOVA, and t-test.

Research Results

Reliability

Five indicators domains of a final PES assessment tool are shown in Table 2. The values by domain and the total standardized values are calculated by taking into account the mean and standard deviation of each domain. Four levels of PES index are level 1-very positive (more than 60.01), level 2-postive (50.01~60.00), level 3-negative (40.01~50.00), and level 4-very negative (less than 40.00). Cronbach α for the tool appeared as 0.963 for 35 items with range between 0.861 and 0.908, indicating good reliability. Fitness of five factor model by confirmatory factor analysis shows X^2=6359.617 (df=550; p<.05), CFI=.859, TLI=.870, RMSEA=.076, indicating fairly good model (good acceptance level: CFI, TLI> 0.8; RMSEA: 0.05~0.08).

Table 2. Five indicator domains of PES assessment tool and its reliability.

Indicator domain (#)	Operational definition	Subcomponents (# of items)	Reliability
science learning emotion (6 items)	Various emotional features that have been shown to influence science learning	Positive learning emotion (3); Negative learning emotion (3)	.861
science related self-concept (6 items)	Thoughts and confidence that students have about themselves in science learning	Self-efficacy (3); Self-esteem (3)	.900
Science learning motivation (10 items)	State of mind or will to study a specific task in science learning	Willingness (2); Participation (2); Attention (2); Relevance (2); Goal orientation (2)	.872
Science related career aspiration (5 items)	Motivation or will to choose and maintain science, engineering, technology related career path	Career recognition (1); Career value (2); Career interest (1); Career will (1)	.895
Science related attitude (8 items)	Perception and recognition of the role of science and scientists, curiosity and interest in science, awareness of the value of science	Value of science (3); Perception of science (3); Interest in science (2)	.908
Total	35 items		.963

Differences by Grade Level

It appeared that the PES scores significantly ($p<.0001$) decreased from grade 4th to grade 10th (see Table 3). Elementary students had higher PES scores than those of middle and high schools, while there were no significant differences between middle and high school students.

Table 3. Differences of PES assessment test scores by grade level.

Grade	4th (n=386)	6th (n=399)	8th (n=490)	10th (n=556)	F	p
mean ±SD	53.1±9.0 ^{a}	50.7±9.8 ^{b}	49.0 ^{c}	48.3 ^{c}	22.0	.0001

* Different small letters (a, b, c) at the upper corner of statistical values indicate significant differences in groups.

Differences by Gender

It appeared that PES scores were significantly ($p<.0001$) higher in male students than female students (see Table 4). Male students perceive science learning more positively than female students. This result was similar to previous international studies of Debacker & Nelson (2000), George (2006), and Weingburgh (1995).

Table 4. Differences of PES assessment test scores by gender.

Gender	Male students (*n*=949)	Female students (*n*=892)	*t*	*p*
Mean ±SD	51.4±10.2	48.5±9.5	6.44	.0001

Differences by Participation in Science Related Extracurricular Activities

It appeared that PES scores by students with participation in science related extracurricular activities were significantly (p<.0001) higher than those without participations (see Table 5).

Table 5. Differences of PES scores by students' participation in science related extracurricular activities.

Category	Students with participation (*n*=1,012)	Students without participation (*n*=768)	*t*	*p*
mean ±SD	52.0±9.9	47.7±9.6	9.13	.000l

Conclusions and Implications

A PES assessment tool was found to have a good validity as well as reliability. There are statistically significant differences in the norm distribution and scores of PES assessment test by grade level, gender, and participation in science related extracurricular activities. It is important to pay more attention to improve instructional strategies as well as science education policies for middle and high school students and female students to have positive experiences about science. It also implies that instructional strategies and science education policies can function as a parameter of effectiveness in enhancing students' affective achievements in science. However, the PES assessment tool is newly developed and currently administered in Korea. It may be promising to use in other countries to draw implications as international comparative studies.

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Appendix

Assessment Tool for Positive Experiences about Science (PES).

A. Emotion in Science Learning	C8. The contents learning in science class can be used in my daily life.
A1. I enjoyed science class.	C9. It is important for me to understand in science class.
A2. I was satisfied with science class.	C10. It is important for me to successfully accom-plish
A3. Science class was interesting.	tasks and activities in science class.
A4. Science class was boring.	D. Science related Career Aspiration
A5. Science class was annoying or troublesome.	D1. I learned about science related jobs.
A6. I was nervous or frustrated in science class.	D2. I think science-related jobs give me an oppor-tunity
B. Self-concepts in Science learning	to learn and develop on my own.
B1. I can solve tasks and activities given in science class very well.	D3. Science-related jobs have a great impact on our society.
B2. It is easy for me to study science.	D4. I became interested in science-related jobs.
B3. Science is one of my favorite subjects.	D5. I want to have a science-related career in future.
B4. I am recognized by teachers and friends in science class.	E. Science-related Attitudes
B5. Through science class, I feel like I am important person.	E1. Science helps make this world a better place to live.
B6. Science class makes me to be satisfied with myself.	E2. Science is worth studying.
C. Motivation in Science Learning	E3. Science is useful even after school graduation.
C1. I try to do my best in science class.	E4. Science development has influenced on devel-opment
C2. I spend a lot of time studying science.	of environment, technology, and society and vice verse.
C3. I participate actively in science class.	E5. It is desirable to increase time for science class.
C4. I ask many questions especially in science class.	E6. Scientists think and judge reasonably and logically.
C5. I concentrate on my science class and not being distracted.	E7. I want to know more about science.
C6. I often think of something else not related to science class.	E8. I like science-related experiences (reading, field
C7. What I learned in science class is relevant to me.	trips, watching science videos, etc.).

THE USAGE OF STEAM PROGRAM IN DEVELOPING AND IMPROVING OF STUDENTS' EXPERIMENTAL SKILLS

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Abstract

The research analyzes the usage of STEAM program "Cognition of Energy and Thermal Processes" for students of ninth (1st Gymnasium) classes in order to deepen and broaden the knowledge of natural science education, develop practical abilities of students and their scientific researcher's competence. Students were advised to do five experimental works in this field. The program engages a basic educational strategy – inquiry based learning. The results of the pedagogical experiment and the questionnaire survey are discussed. Summarizing the results of the research, it can be stated that educational experimental activities are necessary and useful for students. By using the experiment, students can be provided with educational material in an attractive form, which stimulates the interest in the subject. Program participants have deepened and expanded their knowledge of energy and thermal processes in nature. Students improved their competence in natural science research. They learned how to plan and perform experiments, acquired the ability to formulate hypotheses, to make assumptions, to analyze and explain results, and to formulate reasoned conclusions. Students acquired practical skills to work properly and safely with devices and tools (computer systems Nova 5000 and Xplorer GLX, temperature, humidity sensors, caliper, scales, etc.) Students liked to be young researchers; they felt the joy of discovery by practically experimenting and independently exploring natural phenomena.
Keywords: *inquiry-based learning, experimental skills, science learning, STEAM education.*

Introduction

Most educational strategists, scientists, and practitioners in advanced countries keep up-to-date STEM subjects and their teaching, taking into account the rapid change in the field of science and technology and the rise of interdisciplinary integration. Fan and Yu (2016) pointed out that STEM education was focused on curriculum reform in many countries. This is because a number of advanced countries have fully realized that students' academic performance in science, technology, engineering and mathematics determines the country's economic development and competitiveness. Emphasis is placed on student-centred, constructivist education responding abilities of each student and suitable for all students. Worldwide practice uses various methods for updating and promoting STEM subjects. Many scientists suggested that inquiry-based learning strategy should be used to promote technology exploration, to practice teaching at a higher level, and strengthen the effect of STEM. According to many scientists, inquiry-based learning approach should be applied in schools (Abdi, 2014; Connor, Karmokar, &

Whittington, 2015; DeJarnette, 2012; English, 2016; Erickson, 2013; Filippi & Agarwal, 2017; Gormally, Brickman, Hallar, & Armstrong, 2009; Kelley & Knowles, 2016; Kennedy & Odell, 2014; Krajcik & Delen, 2017; Lai, 2018; Lee, 2011; Stohlmann, Moore, & Roehrig, 2012; Yakman & Lee, 2012).

Inquiry-based learning strategy can help to deliver a deep and meaningful science education, increasing the interaction between the student and the concepts under investigation. Interactive, multimedia experience cannot replace the real laboratory work but can enhance the learning process of many students, help them find the relation between the theoretical principles and the observed behaviour in an easy and intuitive way (Avouris, Tselios, & Tatakis, 2001). Since science is an experimental science, the role of lab-work in science education has been often paid attention by research studies (Bernhard, 2003; Harms, 2000; Sassi, 2001).

In order to make students more interested in natural sciences and to motivate them to relate their life to STEAM activities, it is appropriate to encourage students to engage in independent research and to discover the joy of discovery. One of the ways to solve this problem is the students' practical experimental activity in the laboratories of University. Since Science is an experimental subject, the role of practical activities in science education is very important. Experimental activities are one of the main science teaching/learning methods. This research analyzes the usage of STEAM program "Cognition of Energy and Thermal Processes" for students of ninth (1st Gymnasium) classes in order to deepen and broaden the knowledge of natural science education, develop practical abilities of students and their scientific researcher's competence. The main goal - to disclose the effectiveness of practical experimental work in science teaching at a high school.

Research Methodology

70 students of ninth (1st Gymnasium) classes from Šiauliai Adult School, S. Sondeckis Art Gymnasium, Romuva Gymnasium, S. Daukantas Gymnasium and S. Šalkauskis Gymnasium were involved in the experiment in 2018-2019. Analyzing the results of the real education process was revealed the effectiveness of practical experimental work. The educational process was based on the STEAM program *Cognition of Energy and Thermal Process*, which was based on inquiry-based learning. Students were advised to do five experimental works at the level II, as structured exploration, and level III, as guided exploration. Experimental works were used an inquiry-based approach, based on a small-scale research activity. Students were asked to do five experimental works for 2 hours each. Works were done in groups of two. Experimental works were carried out at Šiauliai University laboratory using the available equipment and tools. Some works have been done using computer-based training systems *Xplorer GLX* and *Nova 5000*. In order to evaluate the students' opinion on this program a survey has been carried out. Data were processed using the SPSS (Statistical Package for Social Sciences) software. Methods of descriptive statistical analysis were used for the analysis of the research data. For each statement of the questionnaire Positive Attitude Index (*PA*) was calculated. The Positive Attitude index may vary from 0 to 1.

Research Results

It can be stated that experimental activity is a necessary and currently integral part of the educational process. By using the experiment, students can be provided with educational material in an attractive form, which stimulates the interest in the subject. All students were satisfied and interested in all the experimental work (*PA* = .96), there were no unresolved difficulties for them (*PA* = .66), they easily understood the experimental methods and workflow (*PA* = .73). Less than a third of students have done similar work at school during school hours (*PA* = .28) and a little over a third were familiar with tools and devices (*PA* = .30). The students indicated that the experimental activities are interesting and engaging; they would like to continue such activities in the future (*PA* = .87). Following a t-test analysis, no statistically significant difference on these issues between the groups (students of different schools) was obtained (null hypothesis H_0 on average equality cannot be rejected; $p > .41$).

Although the students felt that they were doing well in experimenting, they thought they could easily understand the methods and workflow of the experiment, but monitoring and evaluating the activities made it possible to identify the typical difficulties that students encounter in practical work. Most of the students were hurried to do one or the other measurement, not fully understanding the meaning of the whole experiment. The lack of experimental skills was also evidenced by the difficulty for students to organize the work desk properly, to put tools and devices in a convenient and functional way. In most cases, students wanted to do everything while sitting, although this is sometimes very uncomfortable. There was a lack of basic skills to work with small auxiliary tools such as tweezers, tongs, flasks, tubes and so on.

The inquiry steps of experimental work, i.e. how students are able to formulate research problem, hypothesis, how to plan workflow, define variables, how to work with equipment and measuring devices, how to capture, process and analyze experimental data, formulate conclusions was analysed. 76 % of the students successfully formulated a hypothesis and only 12 % of the students, who have worked at inquiry level III, understood and planned the workflow correctly. 65 %t of the students properly processed the results, filled in the tables, drew up the graphs, performed the mathematical calculations, although only 34 % were succeeded in formulation of the conclusions.

Students' attitudes towards experimental equipment and tools used at work, their complexity and expediency were explored. Most students' preferred electronic measuring devices. Students enjoyed working with Science Learning Systems *Xplorer GLX* and *Nova 5000*. Comparing the advantages and disadvantages of the *Xplorer GLX* and *Nova 5000*, *Xplorer GLX* was relatively better (*PA* = 0.91) than *Nova 5000* (*PA* = 0.78). They emphasized that *Xplorer GLX* is easier to manage and the *Nova 5000* is quite inert and slow to operate, often malfunctioning.

Conclusions

It can be stated that in order to strengthen the interest of students in science and to achieve better learning outcomes, it is necessary to organize the education process so that it would be interesting for students. By applying inquiry based learning, students' experimental abilities and skills are developed, curiosity of students is stimulated, and interest in the subject is encouraged. The new, favourite activity of the students is of great importance for better learning outcomes.

It can be stated that the experimental training activity is a necessary and currently integral part of the educational process. By using the experiment, students can be provided with educational material in an attractive form, which stimulates the interest in the subject.

Positive attitudes of students towards STEAM training programs suggest that it is appropriate to use such programs when teaching science.

The typical difficulties that students encounter in practical work were identifying. Most of the students hurry to do measurement, not fully understanding the meaning of the whole experiment. The lack of experimental skills is also evidenced by the difficulty for students to organize the work desk properly. There is a lack of basic skills to work with small auxiliary tools such as tweezers, tongs, flasks, tubes and so on.

The research showed that students formulate the research hypothesis well enough, process data properly, but find it harder to plan workflow and formulate conclusions.

Program participants have deepened and expanded their knowledge of energy and thermal processes in nature. They understood the thermal expansion of the solid bodies, the concept of the specific heat of the material, the properties of the phase transformations of the material, the specific heat of evaporation of the water, the process of heat transfer of the human body and the environment.

Students deepened their competence in natural science research, learned how to plan and perform experiments, acquired the ability to formulate hypotheses, to make assumptions, to analyze and explain results, and to formulate reasoned conclusions.

Acquired practical skills to work properly and safely with devices and tools (computer systems *Nova 5000* and *Xplorer GLX*, temperature, humidity sensors, caliper, scales, etc.)

Students felt the joy of discovery by practically experimenting and independently exploring energy and thermal phenomena. They enjoyed being young researchers.

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THE EFFECTIVENESS OF IMPLEMENTING INQUIRY ACTIVITIES INTO THE TEACHING PROCESS IN THE PHASE OF REVISING AND DEEPENING THE LEARNING CONTENT

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Abstract

The aim of research was to verify the effectiveness of implementing the inquiry-based teaching (IBT) into the teaching process of chemistry in secondary school in the phase of revising and deepening the previous-year learning content. The results of the research confirmed a significant difference on the level of knowledge and skills between the experimental group students (N=143) where the IBT was implemented and the control group students (N=149) where traditional teaching methods were implied.
Keywords: *changes in chemical reactions, inquiry-based teaching, learning content, secondary school students*.

Introduction

In Slovakia, the request of inquiry for the subject of chemistry is anchored in the National Education Programme for Lower Secondary Education (ŠVP ISCED 2, 2014). The subject of chemistry should have a research and an activity character, students should learn through their own experience about the properties of substances, natural relations of their behaviour and their interaction. This request is also related to the constantly deteriorating results of Slovak students in international comparative measures OECD PISA. Slovak students have a good command of natural science knowledge on the level of remembering and understanding, but they cannot think independently about natural science phenomena and connections, observe them, create hypotheses, find and design solutions, interpret collected data, form conclusions and use evidence when arguing (OECD, 2007, 2016). One of the possible ways of solving this problem is the implementation of inquiry-based teaching (IBT) into the teaching process.

The results of many studies pointed out the effectiveness of IBT when acquiring knowledge with regard to the increase of conceptual understanding of concepts and knowledge, development of critical thinking, sustainability of knowledge, development of skills – both scientific and cognitive, increasing motivation and interest as well as forming positive attitudes towards the subject (Akcay & Yager, 2010; Brickman, Gormally, Hallar, & Armstrong, 2009; Bruder & Prescott, 2013; Furtak, Seidel, Iverson, & Briggs, 2012; Hattie, 2009; Marshall & Horton, 2011; McLoughlin, Finlayson, & van Kampen, 2012; Minner, Levy, & Century, 2010; Song & Kong, 2014; Wang, Wu, Yu, & Lin, 2015). These studies focused on the IBT implementation in the phase of approaching the learning content, which is also related to the definition of inquiry.

As the traditional approach to teaching in Slovak schools shows knowledge acquisition only on the level of lower-order thinking, which may assume also a lower knowledge sustainability, our goal was to reach a required level of knowledge acquisition after revising and deepening learning content acquired in the previous year – gained in the following year by means of implementation of the created inquiry activities for the IBT. The implementation of IBT in this phase of teaching process enables to point out the problems of the current education system in Slovakia, that are related to knowledge sustainability and also the influence of the IBT on the level of knowledge acquisition.

Research Methodology

General Characteristics

The main aim of the research was to verify the effectiveness of implementing IBT into the teaching process during the phase of revising and deepening the learning content from the previous year within the "Changes in Chemical Reactions" thematic unit in students of the 8th grade of secondary schools.

A pre-test-post-test design was applied for the purposes of the research.

The research was conducted in the selected secondary schools during the school year of 2017/2018.

The research sample comprised of eleven teachers and 292 students of the 8th grade from eleven classes of secondary schools. The experimental group consisted of five teachers and 143 students and the control group consisted of six teachers and 149 students. The gender composition of the groups was the following: the experimental group with 63 young men and 80 young women and the control group with 72 young men and 77 young women.

Procedures

Pre-tests were realized at the beginning of the research to find out the input knowledge of students – what the students remembered from the "Changes in Chemical Reactions" thematic unit which was taught during the previous school year. Based on the results of the pre-tests, the classes were divided into experimental and control ones. Teachers were also taken into consideration, so that the equality in terms of IBT skills was secured.

Consequently, the teaching process started. In experimental classes the created inquiry activities were used within the revising and deepening of the learning content from the "Changes in Chemical Reactions" thematic unit – five activities overall: "Exothermic and Endothermic Reactions" and four activities aimed at "The Factors Affecting the Rate of Chemical Reactions". Inquiry activities (i.e. the Methodological Sheets for Teachers and Worksheets for Students) were created based on the 5E model (Bybee et al., 2006) and they were intended for the guided inquiry. In control (comparative) classes, teachers used their own way of teaching during the revising process – traditional teaching methods were implemented such as questions and answers method, oral revision, written revision, work with a textbook, demonstration experiments and laboratory works.

After the revising and deepening of the learning content, the post-tests were taken in all of the classes.

Research Instrument

Standardized cognitive tests were used as a research instrument for the pre-tests and post-tests. The tests were comparable, they included the learning content of the "Changes in Chemical Reactions" thematic unit according to the content and performance standards defined in *ŠVP* ISCED 2. They consisted of ten items which were aimed at the following levels of cognitive field, based on the revised Bloom taxonomy (Anderson, Krathwohl, et al., 2001): remembering (1 item), understanding (4 items), applying (4 items) and analysing (1 item).

Data Analysis

When processing data, the tools of phenomenological analysis, descriptive and inductive statistics were used (Kolmogorov-Smirnov test to determine the normality of data distribution and a nonparametric Mann-Whitney U-test to verify the hypotheses of the research).

Research Results

Kolmogorov-Smirnov test confirmed that the gained data ($p < .05$) are not normally distributed, thus we used a nonparametric Mann-Whitney *U*-test to verify the main hypothesis. For statistic verification the main hypothesis was formed as follows:

H_0: There is no significant difference between the level of knowledge and skills of the experimental group students and the control group students after revising and deepening the learning content.

H_a: There is a significant difference between the level of knowledge and skills of the experimental group students and the control group students after revising and deepening the learning content.

Here, level is understood as an increase of knowledge and skills in cognitive field on the following levels – remembering, understanding, applying and analysing.

The results of the statistic verification of the main hypothesis are listed in Table 1.

Table 1. The results of the statistic verification of the main hypothesis.

Statistics	Value	Description	Conclusion
Z	-6.095*	H_0 rejected	There are differences
Asymp. Sig. (2-tailed)	.001		

**. The main difference is significant at the .05 level.*

Conclusions and Implications

Statistic verification of the main hypothesis proved that in the phase of revising and deepening the learning content the IBT was more effective than traditional approach to teaching considering the higher level of students´ knowledge and skills. It was particularly proved in the items aimed at the higher-order thinking and with the students with lower academic achievement (those with grades of 3 and 4). The given findings can help improve the results of Slovak students in international measures OECD PISA. It is proved also by the conclusions of the national report PISA 2015: "The way of teaching natural science subjects significantly influences the level of scientific literacy in students (Miklovičová, Galabová, Valovič, & Gondžúrová, 2017)."

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THE INTERNATIONAL YEAR OF THE PERIODIC TABLE: AN OVERVIEW OF EVENTS BEFORE AND AFTER THE CREATION OF THE PERIODIC TABLE

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Abstract

It has been 150 years since D.I. Mendeleev formulated the Periodic law and expressed it visually in the form of a table of elements in 1869. As is clearly well known today, Mendeleev's ideas, confirmed by the discovery of the elements he predicted, turned out to be very promising indeed. However, Mendeleev was not the first, nor the only scientist to have investigated the periodic arrangement of the elements. With this in mind, the present paper seeks to highlight some of the other efforts made in the field during Mendeleev's lifetime.
Keywords: *D. Mendeleev, periodic table, table options, history of science*.

Introduction

If we examine the decade preceding the creation of Mendeleev's periodic table, we will find that several attempts had already been made with a view to classifying elements according to their atomic mass.

Among such endeavors it is possible to note the tables offered by William Odling (England, 1857-1864), the spiral offered by Alexandre-Émile Béguyer de Chancourtois (France, 1862), the octaves offered by John Alexander Reina Newlands (England, 1864) and the tables offered by Julius Lothar von Meyer (Germany, 1864, 1870). These were all proceeded, however, by the very first effort made in this direction, namely were the triads proposed by Johann Wolfgang Döbereiner (Germany, 1817-1829). These aforementioned attempts have already been examined and studied in detail by earlier scholars which are cited in the full version of the present article and which are also presented in a visual form.

Unfortunately, it should be recognized that all these scientists had also failed in either finding the key thread in their assumptions (which were later shown to be correct), or in correctly interpreting the patterns in their theoretical framework. In this respect, it should be noted that even D. Mendeleev himself and his colleagues even were forced to defend the priority of their discovery (Mendeleev, 1871a; Chugayev, XVI).

Moreover, it is especially important to note that none of the attempts that preceded Mendeleev's 1869 publication made it possible to fully establish a general pattern applicable to all the elements that were known at the time of publication of his periodic table. In addition, none of them even provided for the possibility of correcting atomic masses, let alone for the possibility of predicting (!) undiscovered elements. Indeed, and almost forty years later, D. Mendeleev himself wrote in his diary: “Apparently, the future law does not threaten periodic law with destruction, but only superstructures and development promises” (Dobrotin). These words turned out to be prophetic. 63 elements were known in 1869, while 118 elements are known as of 2019, and yet all can be placed uniquely in Mendeleev’s table.

At least 700 different versions of Mendeleev’s table have been offered thus far. Some of these are based on the search for a mathematical justification for periodic dependence, while others are an attempt at a graphical representation of the laws of nature.

With this in mind, the present study seeks to consider and study several types or versions of periodic tables proposed by their authors during Mendeleev’s lifetime.

Types of Periodic Tables

As proposed in the initial model, and as a general rule, 19th century scientists only considered a short, 8-column, form of the periodic table of elements, which is why we only considered these versions of the tables included in the present study. Furthermore, the scientists, who offered suggestions pertaining to the placement of elements in a graphic form, included Danes, Germans, and Britons, as well as Russians. This, in turn, serves to underline the argument suggesting that science has no boundaries and that true discoveries always become the property of and belong to the humanity at large rather than to a particular nation.

As we noted above, the chemical community was well aware of the fact that several dozens of attempts to classify elements had been made before our great compatriot, D.I. Mendeleev, plunged into this question. The methodological needs associated with the preparation of a student textbook, based on a single logical system, was what - in large part - led Mendeleev to the formulation of a law, that objectively existed in nature, but was unknown to any scientist at that point in time. The textbook in question was Basics of Chemistry (Mendeleev, 1868), which contained Mendeleev’s own formulation of the law, as follows: “the physical and chemical properties of elements, manifested in the properties of the simple and complex bodies they form, are periodically dependent (form a periodic function, as they say in mathematics) on their atomic weight” /attributed to D.I. Mendeleev - S.T., E.T./ (Mendeleev, 1871b, p. 941).

Since we work at school, we have the opportunity to acquaint ourselves and our students with the chemical-historical events of the 19th century. In this respect, we will focus on the rather rare versions of the table of elements stored in our school’s small collection. Moreover, we also wish to posit that the tables considered below are of historical and chemical, as well as chemical and mathematical, interest. With this in mind, we shall begin our journey with the periodic table proposed in Kazan by F. Flavitsky (Figure 1) in 1887 (Flavitsky).

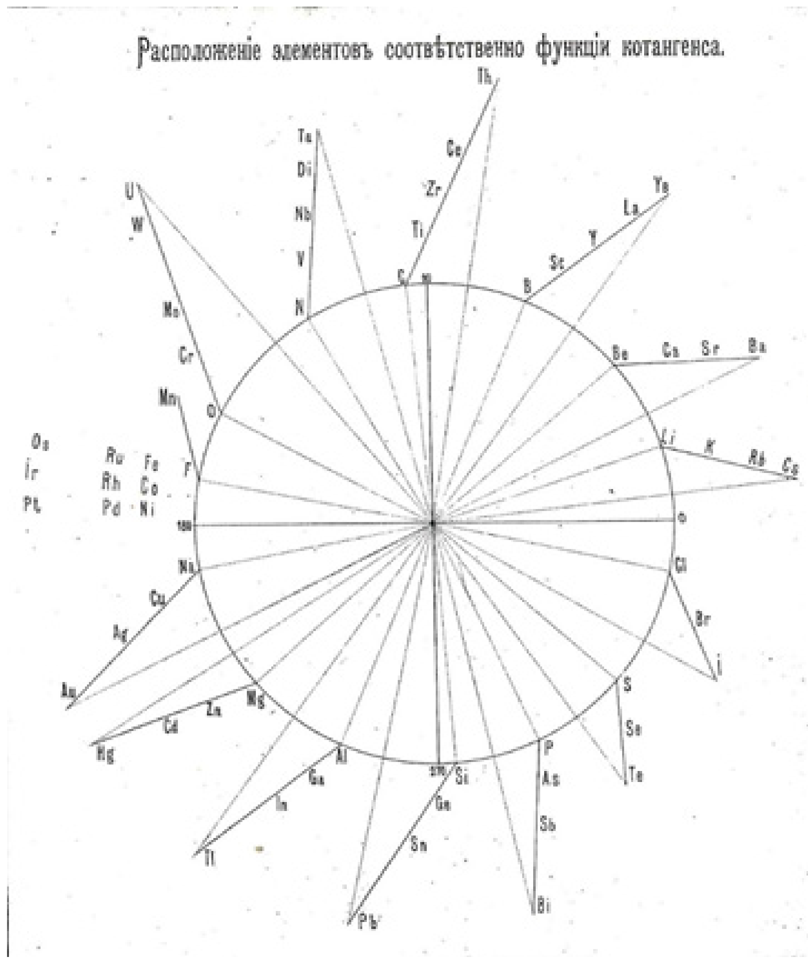

Figure 1. The location of the elements, with respect to the cotangent function by F.M. Flavitsky.

The next stop in our journey is the table proposed by Lothar Meyer in 1894, which is interesting because it is presented on a cylinder (Meyer). We will then proceed to the table offered by J. Thomsen from Denmark, in 1895 (Thomsen, 1895a, 1895b); the spiral triangle offered by N. Delone of St. Petersburg, in 1898 (Delone) and the spiral eight (the first spatial table) offered by W. Crookes of London, in 1898 (Crookes).

With this in mind, it is worth noting that Mendeleev himself opined that "…the spiral arrangement of the elements ... I consider it marginally applicable and largely artificial…" (Mendeleeff, 1871a, p. 352). While this is probably true from a scientific perspective, visuals are also important when teaching students and it is in this respect that spiral versions of the table offer a clear advantage.

Our journey ends with a study of the periodic table proposed by the artillery colonel Nikolai Nechaev in 1893 (Figure 2) (Nechaev). Nechaev's approach to the table is original in two respects: Firstly, it is a special, rather than a planar, representation of periodic dependence. Secondly, Nechaev presented his table in the form of a projection of rotational bodies onto a plane represented as truncated cones installed alternately in the form of a tower, of which there are no surviving copies.

That said, we would also like to mention one more version of the periodic table, namely the one offered by V. Ipatiev. Ipatiev's version was one of the first to have been applied in a school textbook, and is also concise and accompanied by a detailed methodological commentary. More specifically, Ipatiev is important in directing our attention to the fact that an essential feature common to all elements should be chosen if the elements are to be systematized. Furthermore, Ipatiev also offered another crucial insight in arguing that this selected feature must satisfy certain conditions, namely: 1) it must be measurable, 2) it must be common to all elements and 3) it must be paramount, i.e. that all the remaining properties of the elements must depend on it [Ipatiev].

Figure 2. Scanning of the projection of rotational bodies in the form of truncated cones as used in Nechaev's spatial construction of the periodic system, 1893.

In this respect, we would like to first and foremost direct the reader's attention to the fact that only Crookes' 1898 table (Crookes) contains the inert elements.

It is important to note that many variants of the periodic table of the elements are accessible to those who wish to study them. Particularly instructive in this respect is the collection assembled by the famous chemist and science communicator, as well as a participant of the XXIst Mendeleev Congress scheduled for September, and the Vice President of the London Royal Society, Nottingham University Professor Sir Martyn Poliakoff. Professor Poliakoff also kindly presented part of his collection at the second chemistry teaching conference in Moscow in February 2019. A similar collection is also available for public viewing at the Riga Polytechnic University. This second collection was gathered and donated to the university by Mikhail Gorskis (Iecava, Latvia).

Finally, we wish to stress that the table versions presented by us above are rare and are not necessarily part of either the Poliakoff or Gorskis collections.

Conclusions

D.I. Mendeleev conceived and formulated a system of elements, about which he quite deservedly argued that: “it would be more correct to call my system periodic because it follows from the periodic law” (Mendeleev, 1871b). The publication of his table also represented the breaking of a metaphorical intellectual dam in the sense that sources suggest that between 500 and 700 versions of the table have been published or discovered thus far! Note, however, that these are all versions of *Mendeleev’s* original periodic table of elements!

We would also like to note that the original version of the table prepared by Mendeleev himself and sent to colleagues in February 1869 entitled “The experience of a system of elements based on their atomic weight and chemical similarity” [Journal]. In light of this, it is possible that subsequent translations sounded like “periodic table” and were offered without the name of the author. It is also quite possible that Mendeleev’s name itself will be included in the title of the table of elements in he created as we celebrate the 150th anniversary of its creation.

In closing, we hope that this study, which has plunged you into chemical antiquity, will also allow you to better understand how you can reach the highest peaks in science by joining forces with the global scientific community!

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GUIDELINES IN THE ELABORATION OF A TEACHING SEQUENCE OF KINEMATICS ACCORDING TO A HISTORICAL APPROACH

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Abstract

The domain of motion or kinematics is important because it forms the basis of mechanics, an important branch of physics. By studying kinematic phenomena in the laboratory, high school students are likely to develop a better understanding of kinematics concepts as well as elements of the scientific approach to study natural and constructed phenomena. However, students encounter difficulties in understanding these concepts, just as in the acquisition of the skills necessary for the accomplishment of the different stages of an experimental process. Therefore, the purpose of this research was to provide guidance, according to a historical approach, which would inform teachers in the design of teaching sequences on the study of kinematics.
Keywords: *conceptual understanding, high school physics education, historical approach, kinematics.*

Introduction

If there is a domain that causes a lot of difficulties to students, it is kinematics, defined as the study of the motion of objects without worrying about its causes. There are several reasons for this. First, students have, before arriving in physics courses, extensive experience on properties of the motion they acquired in their interactions with events of their daily lives. This experience allowed them to build for themselves a set of cognitive schemas to interpret motion phenomena. These schemas are well adapted to the tasks of everyday life: to ride a bicycle, to catch an object, etc. However, they can interfere with learning scientific concepts, especially if the teaching does not take them into account (Trudel, 2005). A second reason for the difficulty of kinematics is about how one teaches it in introductory courses to physics. Indeed, kinematics is often approached using a mathematization which students are not used to. For example, a current pedagogical practice consists in bringing students, at the beginning of the study of kinematics, in the laboratory where they measure different properties of the motion that they then put into graphics. Back in class, they analyze the results obtained and carry out calculations using formulas to get the values of speed and acceleration. However, it seems that students perform these various operations without a real understanding of what they do (Trudel, Parent, & Métioui, 2009).These difficulties are reminiscent of those met by scientists, during the course of history, in the development of new scientific theories. These similarities between the conceptions of students and those expressed by scientists at different times suggest that the history of science can inform us on concept development in students. Thus, a historical approach to teaching science can facilitate the development of scientific skills targeted by the physics program in secondary school.

In the first place, it could be used to favor the acquisition of investigative skills scientist among students. For example, in the study of projectiles, an adaptation from Galileo's original experience (done in 1609) would compare student results to those obtained by this scientist, and so discuss the relative merits of the experimental methods used (Borghi, De Ambrosis, Lamberti, & Mascheretti, 2005). Second, a historical approach would allow the student to situate the process of science development according to different historical and cultural approaches (Monk & Osborne, 1997). In this respect, science teachers can incorporate historical examples to demystify certain prejudices that are negative, especially in the case of physics. Students can develop an understanding of human dimensions associated with the development of science, the nature of scientific knowledge and the impact of technological applications in society. Thus, students will become familiar with the contexts of scientific discoveries that extend well beyond communication of scientific facts. Third, a historical study of scientific discoveries can guide the teacher in designing rich activities, involving different dimensions of scientific activity, thus providing his students with the opportunity to deepen their understanding of scientific phenomena (Mayer & Kumano, 1999). These activities could draw inspiration from problems, experiences and solutions put forth by scientists in their discoveries. Indeed, to realize these, they had to solve problems belonging to several dimensions: conceptual (restructuring), methodological (development of experimental methods to verify theories) and epistemological (the nature of knowledge becomes accessible to reason through dialogue and the test of experiences) (Bertoloni Meli, 2006). Hence, the mastery of these different dimensions is associated with a deep understanding of scientific phenomena (Mayer & Kumano, 1999).

Despite these advantages, there are several obstacles to the use of the history of sciences for educational purposes. Among those, lets mention time constraints associated with program coverage and the difficulty of finding historical resources of quality. In addition, some students may have difficulty to understand the point of view of past scientists. For example, they may consider these scientists (especially those whose theories have been replaced by more modern) as inferior when comparing their modes of thinking to those of today.

Historical Approach in Teaching and Learning Sciences

By inscribing their historical approach of science education according to a constructivist approach, Monk and Osborne (1997) recommended that the construction of scientific knowledge be explicitly part of the educative process. Indeed, it is only by overcoming the obstacles created by the use of their misconceptions that students can develop an in-depth understanding of the motion phenomena and the nature of science. Therefore, it is important that they can reflect and share their knowledge about the kinematics phenomenon under study. In addition, the development of conceptual understanding should be done in parallel rather than being confused with the development history of the kinematic concept, like the parabolic motion. Indeed, the previous conceptions of students look more like a pre-paradigmatic reflection rather than the theories of past scientists. In this respect, it can be emphasized that students are certainly not as thorough and systematic in their interrogations about the natural world than these scientists.

These considerations provide science teachers two more reasons to include the history of science in their practice. First, the historical approach facilitates expression and discussion of students' misconceptions by making them worthy of consideration to their eyes. Indeed, in this approach, it is easier for them to accept the erroneous character of their conceptions if they can find similarities with those scientists from different times. Second, by discussing historical development history of a science concept, the students are in a better position to recognize the inadequacy of their previous understanding and the improvement that constitutes the current scientific conception. By incorporating these constructivist principles to their historical approach, Monk and Osborne (1997) proposed an approach in six phases:

1. During the first phase, the *Presentation*, the teacher presents to students a motion phenomenon (for example, a marble falling down an inclined rail) and discusses with them its properties so as to make it problematic inviting them to make predictions about its behavior.
2. In the second phase, *Expression*, students are invited in small groups to share their own ideas and theories concerning a phenomenon of motion to provide multiple points of view on how it could be explained in an atmosphere of respect and hospitality (Trudel, 2005).
3. During the third phase, the *Historical study*, the teacher introduces a richly contextualized example including, for example, the first ideas expressed about acceleration of a free falling ball or descending an inclined rail, the social and economic context of time, the different theories issued by scientists and some known facts in support of one or the other interpretations. In this phase, the student is encouraged to consider the multiplicity of possible points of view in the study of the phenomenon in order to better understand the circumstances and the reasons that motivated support for a theory rather than another. The information may come from various sources: historical films, vignettes, reproduction of historical instruments, computer simulation of historical experiences (Borghi & al., 2005).
4. In the fourth phase, *Experimentation*, the teacher invites his students to work in small groups to design experimental tests allowing to determine which of the ideas expressed, contemporary (i.e. students) or historical, is "correct". Given the time constraints and from the variety of ideas put forth, it is preferable that collection and data analysis be done using software (Trudel & Métioui, 2010).
5. The fifth phase, the *Scientific Explanation*, allows the teacher to present the modern version of the phenomenon. This version can then be compared to different theories emitted by past scientists and ideas from students. The version scientist must be presented as a possible explanation among the ideas expressed.

6. In the sixth and final phase, the *Review and Assessment*, students work in small groups to compare the "pros and cons" of each idea expressed and realize that, if the scientific version allows to explain the various properties of the phenomenon satisfactorily, the other points of view also possess merits. The student learns to use scientific evaluation criteria to judge the value of an idea or a theory.

Guidelines for Designing a Historical Approach to the Teaching of Kinematics

A historical approach is particularly useful to facilitate learning of kinematics. Indeed, kinematics concepts have developed over a long period of time benefiting from the contribution of several generations of scientists. It is therefore easy for the teacher to bring out the transient character of the ideas expressed on this topic over time, while pointing out that most of these ideas had been in progress in their time. In this respect, such an approach would allow students to better understand how scientific ideas are accepted or rejected on the basis of empirical evidence and how controversy can arise concerning the interpretation of these evidences. Thus, the development, using the historical approach, of a better understanding of the scientific process in a context of discovery of new knowledge, seems related not only with the main skills of the physics program but also with a constructivist approach. These different considerations concerning the study of kinematics according to a historical approach lead one to propose the following guidelines:

1. The activity must demonstrate the complexity of the development of kinematics and the interactions between members of the scientific community to develop a better understanding of the phenomena of motion.
2. The activity must be linked to the framework of the current curriculum of kinematics to make teachers of science willing to use it. In this respect, the activity should aim to link scientific knowledge (products) with processes (methods) who gave birth to them (Monk & Osborne, 1997).
3. The activity must be in harmony with current teaching practices of teachers in kinematics to meet their needs in including the history of science in their teaching while emphasizing its complementary nature to highlight the social, cultural and epistemological aspects of construction of scientific knowledge.
4. The activity should describe the authentic work of scientists in the context of the development of science (Van Driel, De Vos, & Verloop, 2006).
5. Teachers should be sensitive to shortcomings of students relatively to the historical approach of the knowledge development about the motion.

Conclusions

The difficulties that students experience in learning kinematics possess similarities to those encountered by scientists of different eras. Despite these similarities between student and scientist approaches, there are several differences, so that a historical approach does not aim only to simply replicate the path of these scientists. Indeed, unlike scientists, the conceptions students have developed so often unconsciously, in interactions with everyday objects, and their private character was not the subject of any debate that would have allowed them to evaluate their merits. It is therefore important that a historical approach incorporates constructivist principles where students have the opportunity to express their ideas, to discuss their merits with their peers, read the ideas expressed by scientists at different times, verify them with the help of experiments and evaluate them according to scientific criteria.

Thus, a historical approach to teaching of kinematics would allow students to better understand how various theories about motion have been proposed, what were the arguments invoked, what empirical evidence or factual evidence had been provided in support of or against each of these theories. Not only will students compare their ideas to those distinguished scholars but they will also be able to better realize the transitory nature of theories, while situating the development of science in a social and cultural context.

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HIGH SCHOOL STUDENTS' MODELS OF RELATIVE MOTION IN PHYSICS

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Abstract

The relative speed concept was chosen since it is linked with the relative nature of motion and it is likely that the students would harbor many alternative conceptions about it. The research objective was to identify the various ways students conceive relative motion. Qualitative data collected in various forms of representation received a categorization analysis. Several models of students' understanding about relative motion had been identified. Suggestions are offered to the classroom teacher to help his students understand relative motion.
Keywords: *relative motion, POE tasks, high school physics education, conceptual understanding*.

Introduction

The study of relative speed causes a lot of difficulties to students (Walsh, Dall'Alba, Bowden, Martin, Marton, Masters, Ramsden, & Stephanou, 1993). Hence, the difficulties encountered in trying to understand constant motion are compounded in the case of relative motion, such as pursuits of objects with parallel trajectories but with different speeds (Reif, 2008). Regarding the physical situations involving relative speed, the initial and final conditions of their travel must also be taken into consideration. Considering these issues, it is rather surprising that there are few studies that look into students' understanding of relative motion. Following these various considerations, the research aimed to identify the models students used when trying to predict properties of relative motion.

Conception of Activities

As regards the activities of conceptual understanding of relative motion phenomena, we used a concrete set-up. Moreover, we gave students an activity guide allowing them to work in small groups. To help their investigation, the guide proposed to students various activities (questions, graphics to draw, etc.) to guide their modelling process. This process was structured as a POE task (Prediction> Observation> Explanation). The POE task took place in the following way. First the teacher explained each physical situation with the help of concrete set-up placed in the center of the classroom so that each one can see its various features. The teacher mentioned that students would have to predict what would happen to the motion if he was to perform the experiment described in the guide. He also told them that they had to draw the trajectories of the balls and answer the questions in the guide. Students were to proceed to this task individually. As such, while opening their guide, students could read the physical situation in the guide just described by their teacher and answer questions in the space provided in it. These questions asked the student to predict what would arrive if the experience was to be performed and to write their predictions in their notebook.

As for the relative motion, the guide described the situation in the following way. One gives a small impulse to the ball (A) in order that it rolls from one end to the other. The position of the ball A after 1 sec is given in the figure below (see figure 1).

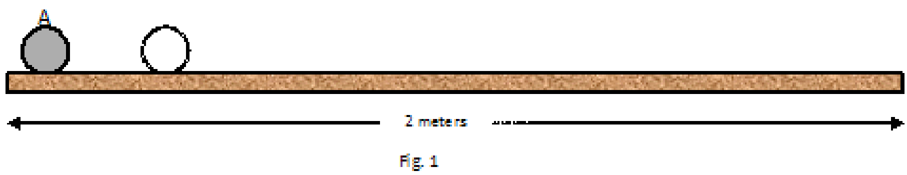

Figure 1. Ball B is rolling toward the right end of the track.

A few seconds later, a second ball (B) is pushed with an impulse larger than ball A on a rail parallel to the first (see Figure 2).

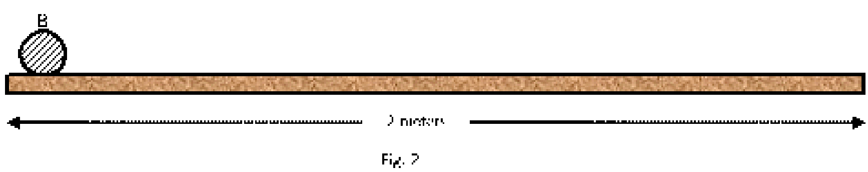

Figure 2. Ball B is launched in parallel track with a time delay.

The guide asked students to draw the expected positions of the ball (A) and the ball (B) in the seconds following the impulse. The position of the ball (A) at 1 second was already indicated. Important reminder: the ball (B) has been pushed with a certain delay relative to the ball (A) (say 2 s) but with a greater impulse. Following their prediction about trajectories of balls A and B, students were asked to write if, according to them, ball B would catch up on A and to explain their answers.

Research Methodology

The sample consisted of two classrooms of 21 and 24 students respectively. These two classrooms were following an optional introductory course in physics in the 11th grade at a high school in the province of Ontario in Canada. The first group was composed mainly of students who had chosen a special orientation toward science offered by the school so that it was reasonable to assume that they were interested in science in general and physics in particular. The second group was composed of regular students and a small number of students with learning disabilities. The teacher of the first group was of feminine gender and had five years of experience in teaching science. The teacher of the second group was of masculine gender and had twenty years of experience in teaching science and mathematics. Both teachers held bachelor's degree in science and a science teaching certificate.

During the experimentation, the main researcher or one of his research assistants were present at each of the periods to observe the unfolding of the events and collect students' answers to the questionnaires in the guide. This research implemented a qualitative case study approach for collecting and analyzing the data (Karsenti & Demers, 2011). In order to study the students' conceptions about relative motion, we analyzed the content of the activity guide students had to fill. Answers written by students in the guide were expressed in different ways: text when answering questions, iconic in sketches of the moving ball. Qualitative data collected in these various forms received a categorization analysis (Miles, Huberman, & Saldaña, 2014).

Research Results

Each student's answers were analyzed in the framework of a multiple-cases study (Yin, 2014). However, due to space limitations, this section presents only the principal students' models identified in this research. These models emerged from the analysis of students' predictions about the set-up presented to them by the teacher and before any experiment was done. Let us remember that the main task of students was to draw the position of both ball A and B on a graphic presented to them (see Figures 3 and 4) and to predict if ball B would catch up on ball A and to explain their answers.

With respect to the first student (St1), his prediction about the motion of ball A was that it undergoes a constant motion (which is evidenced by the constant spacing between adjacent time intervals) (see Figure 3). Similarly, he predicts constant motion for ball B but with longer spacing that reflects its greater speed. However, he does not mention the difference in initial conditions since ball B was launched with a time delay respectively to ball A (see figure 3). However, to the question about Ball B catching up on A, St1 wrote: "Ball A goes at a constant speed. Ball B is pushed one second later than ball A. The balls will meet between the 2nd and 3rd seconds. Ball B completes faster its journey."

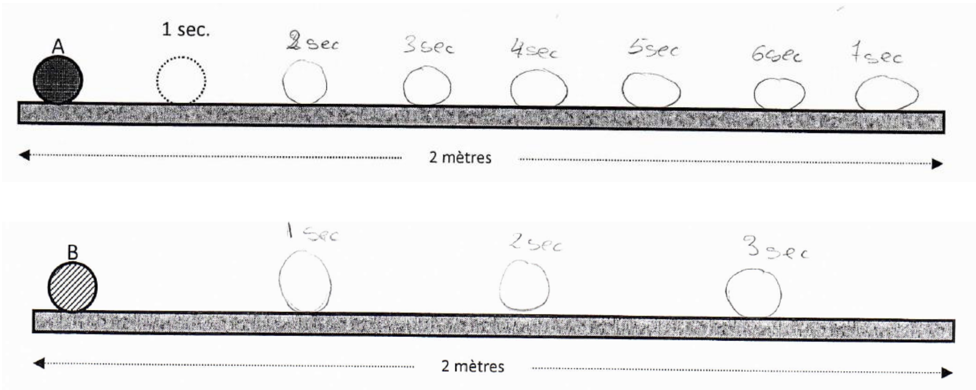

Figure 3. Prediction of St1 about the relative motion of balls A and B.

Other students' models have also been identified in a similar way. For example, the trajectories that student St2 drew for both balls A and B showed non uniform motion (see Figure 4).

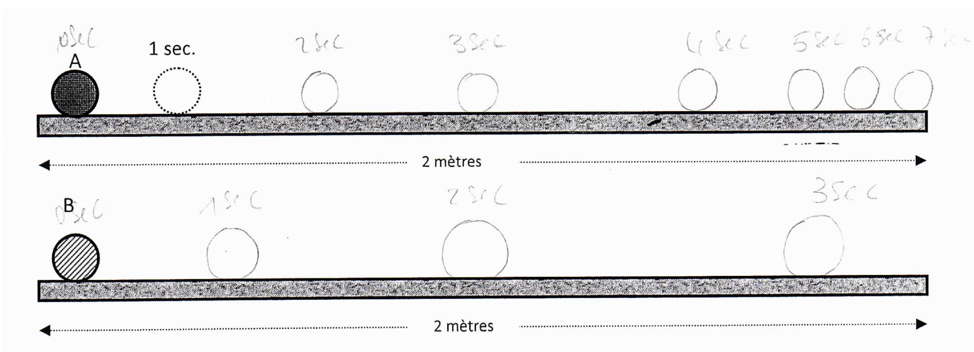

Figure 4. Prediction of St2 about relative motion of balls A and B.

More specifically, St2 student explained that the speed of ball A would increase in the first half of its trajectory and would slow down in the second half. Furthermore, St2 made the prediction that the speed of ball B would increase uniformly. St2 also predicted that ball B would eventually catch up with A since it was thrown with a higher speed. Table 1 below described the various models of relative motion identified.

Table 1. Students' models of relative motion.

	Trajectory of ball A	Trajectory of ball B	B catch-es up on A	Time de-lay	Time scales of A and B	# of students (%)
Model 1	Speed stays constant	Greater con-stant speed	Yes	No	Independent	18 (40 %)
Model 2	Speed stays constant	Greater con-stant speed	Yes	Yes	Independent	6 (13,3 %)
Model 3	Speed increases in first half and decreases in second half	Speed increases regularly	Yes	No	Independent	1 (2,2%)
Model 4	Speed stays constant in the first half and decreas-es in the second half	Speed stays constant	Yes	Yes	Independent	1 (2,2%)
Model 5	Speed stays constant in the first half then decreas-es in the second half	Speed increases regularly	Yes	No	Independent	1 (2,2%)
Model 6	Speed stays constant in the first half then decreas-es in the second half	Speed decreases regularly	Yes	No	Independent	1 (2,2%)
Model 7 (inter-me-diate)	Speed constant	Greater con-stant speed	Yes	Yes	Dependent	6 (13,3%)
Model 8 (scientific)	Speed constant	Greater con-stant speed	Yes	Yes	Dependent. (Use model for problem solving)	1 (2,2%)
Absent or insufficient information						10 (22 %)

Discussion

If one examines the results presented in table 1, there is one common ground that all students agreed upon: Ball B will eventually catch up on ball A, despite they harbor very different models about relative motion. Thus, except for the intermediate and scientific models (model 7 and 8 respectively), it appears that students study motion of balls A and B quite independently and that the main explanation of B catching up on A would be that ball B was launched with a higher speed than A. This explanation does not appear to depend on the time delay or on the specific trajectories of both ball A and B (whether it is uniform or non-uniform). Finally, there appear to be some contradiction between the trajectories drawn by students and their written answers. Thus, we could infer that these students may not have mastered how to transform their predictions into different modalities (trajectories, written statements).

In this respect, students may need to establish links between various factors that have an influence on the relative motion of balls A and B. Indeed, none of these students, to the exception of one (model 8: scientific model), seem to have reached the higher levels of understanding on the scale of Walsh et al. (1993). These higher levels consist of incorporating initial conditions (time delay, initial difference in positions) in their prediction) and furthermore, the establishment of a new entity, the relative speed (Walsh et al. (1993).

Conclusions

In order to improve the efficiency of POE tasks, it is important, according to the results of the present research, to consider the presence of students' models with respect to the specific situation of relative motion that comes under study. These models show that most students considered the motion of balls A and B quite independently. Moreover, the influence of initial conditions upon the relative motion of balls A and B were not well understood by students. Moreover, some students still clung to their naïve models of irregular motion (Trudel & Métioui, 2011), when predicting the horizontal motion of balls, compounding their difficulties. Using these results, a teacher may want to know how to help his students become aware of the influence of initial conditions upon the motion of the balls. In this case, this teacher may present his students supplementary cases where initial conditions, such as the time delay or the initial distance between A and B, are varied. Moreover, small group discussion among students while predicting and experimenting can help them compare and choose the best alternatives among predictions emitted by the members of their team.

Finally, this study has the advantage of showing us that speed comparison problems, and thus relative speed, may be of great complexity for students. Understanding the concept of relative speed may, among other goals, lead students to understand better the role of initial conditions in problem-solving in kinematics. This multiple-cases study involving only two classrooms cannot claim the generalization of results or transfer to the classroom. Future research should involve a more diversified sample of students as well as to cover more scientific disciplines.

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HIGHER ORDER THINKING TASK AND QUESTION APPLICATION IN THE WORLD COGNITION LESSONS IN PRIMARY FORMS

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Abstract

Recently, one has become concerned about the quality of natural science and social education basics of the primary school students. Particular attention is devoted to the higher-order thinking ability education. In the qualitative research, it was analysed what higher order thinking questions and tasks primary school teachers apply in the world cognition lessons. Research data were gathered using a lesson observation method. The gathered data were analysed making a technical picture. Research results showed that primary school teachers proportionally applied lower and higher-order thinking questions and tasks.
Keywords: *world cognition lessons, higher order thinking abilities, primary education*.

Introduction

Today's school should orient itself to students' education for future and to educate critically thinking, creative citizens, able to analyse, interpret, make conclusions. Natural science education in primary school is not only important but also a problematic one, because it comprises various components – ecological, environmental, harmonious development, healthy living and other (Lamanauskas, 2008). Social and natural science literacy learning combining various components and using a real-life context requires from the students to use thinking abilities (Avargil, Herscovitz, & Dori, 2012).

For the lower order thinking abilities scientists tend to attach knowing, knowledge repetition, perception and application (Anderson & Krathwohl, 2001; Thomas & Thorne, 2009; Brookhart, 2010). In other words, this is what does not require a particular thinking activity, more mechanical remembrance and knowledge application. Describing higher order thinking abilities, the researchers (Anderson & Krathwohl, 2001; Thomas & Thorne, 2009) discern such thinking, which they refer to in the activity: analysing, comparison, evaluation, conclusion making, creation, assumption making, new solution searching, information application in the new context. The scientist Brookhart (2010) distributes higher thinking abilities into three categories: *transference; critical thinking; problem solution*.

Teachers apply various types of tasks and questions in the lessons as a means to improve and measure students' understanding, also to assure that a certain subject teaching process takes place (Kerry, 2002). Kerry (2002) pointed out that question types used in a classroom perform an important role in the teaching learning process, because it makes an influence on students' achievements and on the level of participation in the education process. It is important that the teachers apply appropriate questions in the classroom, because students can propose a proper and a thought of answer, if the asked questions are well prepared (Brookhart, 2010).

The scientists (Peen & Arshad, 2014; Jiang, 2014; Shafeei, Hassan, Ismail, & Aziz, 2017) having researched higher order thinking task and question involvement into education process notice that teachers usually apply lower order thinking questions, which are short, one or two word answer, but not higher order thinking questions, which are open and the answer to them is based on the students' opinion. Shafeei, Hassan, Ismail, Aziz (2017) research revealed that teachers agree that higher order thinking tasks are necessary, because they help to develop students' critical thinking, however in the education process more often they apply lower order thinking tasks and questions. This is because teachers lack knowledge about higher order thinking task and question preparation and application in the lessons. Therefore, the authors recommend that teachers were provided with a proper teaching about higher order thinking, that they could successfully develop students' higher-order thinking abilities in their classes. The other research, which was conducted by Peen, Arshad (2014) results revealed that teachers tend to get one student's answer to every question without giving an opportunity for the other students to answer the same question. The researchers make a conclusion that teachers do not expect from the other students an answer to the same question and this apparently does not encourage students' active participation in the lesson. Researchers notice that applying such a questioning way, students seem to finally stop participating in the lesson.

Planning the content of the lesson, teachers should make sure that the prepared tasks will definitely require from students certain knowledge and thinking abilities. It is important that individual tasks and activities include the foreseen teaching content and altogether basically form a common field of the desired knowledge and thinking abilities (Brookhart, 2010). For the content, thinking ability and evaluation balance planning, the scientist Brookhart (2010) suggests using *technical picture* – a certain tool, necessary to guarantee that the task and question collection reflect the width and depth of knowledge and abilities, foreseen in the teaching goals. This is a plan, which helps to hold content knowledge and thinking ability balance, based on task and question collection.

It is noticed that teachers developing students' higher-order thinking abilities encounter certain challenges. In order to understand social and natural science education peculiarities working in primary schools and higher order thinking ability expression during world cognition lessons, research aim was raised to analyse, what higher order thinking questions and tasks primary school teachers apply in the world cognition lessons, i.e. to ascertain what balance the teachers hold between the lower and the higher level tasks and questions; what thinking category tasks and questions usually teachers apply in the world cognition lessons; what higher order thinking tasks and questions prevail in different classes according to students' age. This research is a part of a carried out *qualitative case study* research according to Yin (2011).

Research Methodology

General Characteristics, Research Sample

The research was qualitative, carried out according to Yin (2011) *case study* methodology. It was carried out between October 2018 and March 2019. In the article, a general research part is presented.

The research was performed in one Kaunas primary school. It was chosen as *a case*, taking into consideration the fourth last year (2015, 2016, 2017, 2018) 2nd and 4th form students' National students' achievement assessment (PISA) results, which are openly announced in the school's internet cafe. According to the mentioned results, school students develop high higher- order thinking abilities.

In the article, the method of the presented part of the research is lesson observation. Four world cognition lessons in the 1-4 forms were observed and filmed, one in each form. Before filming all student parents' written agreements and primary school teachers' verbal agreements were obtained about the possibility to carry out observations and visual recordings in their classes. The lesson duration in form 1 – 35 min, in forms 2-4 – 45 min.

Research Procedure

During the observation all tasks and questions were fixed, which primary school teachers applied in the lessons. Research data were fixed in the task and question *technical picture* (see table 1), made according to Brookhart (2010) presented *technical picture* model. All the tasks and questions were recorded, analysed and discussed according to the indicated aspects in the research aims, i.e., it was stated what balance the teachers held between the lower and the higher order thinking questions and tasks; what thinking category tasks and questions teachers usually applied in the world cognition lessons; what higher order thinking tasks and questions dominated in different forms according to the students' age.

Table 1. Task and question *technical picture*.

Form	Lower order thinking abilities	Higher order thinking abilities		
	Knowledge, understanding, application	Transference	Critical thinking	Problem solution
I				
II				
III				
IV				

Research Results

In the first form the teacher raised a lot of questions, both of the lower and the higher thinking order. All the questions were very well thought of by the teacher, activated and motivated students for work. Frontal work dominated in the lesson, however constantly discussions were raised based on students' reasoning and argumentations. Knowledge, understanding and application questions were usually raised seeking to remember what the children knew on the discussed topic. Raising higher order thinking questions, the teacher referred to students' answers to lower order thinking questions, in this way deepening students' understanding and activating their critical thinking. Very often, in the first form the teacher asked students to compare the concepts, reason about similarities and differences, however, was short of students' argumentation to the spoken up reasonings. The teacher encouraged the students to discern similarities and differences, to group information, to single out the gist, to reason about the causes and consequences, to discern insignificant things. Two problematic situations were raised for the students, which they solved working in groups. The situations were not complicated but very lifelike and close to the students' environment. Working in the lesson, the students very often raised thinking questions themselves, answering to which thought critically; willingly referred to their experience, gave their examples on the discussed questions.

In the second form world cognition lesson, knowledge and understanding information was dominating about objects, phenomena and their features. There were given more lower order thinking questions and tasks than the higher thinking order ones. The students were mostly asked about direct information, which was given in the presentation, also, they were asked to tell what they knew about the discussed topic. This could be related to the fact that a new topic was discussed, new knowledge and understanding were obtained, therefore, the main attention was devoted to the new information uptake. In the lesson, various work forms were applied – frontal, work in groups, independent work, however, the tasks which the students performed, were mostly oriented to knowledge and understanding. First, the teacher asked the students about their experience, what they already knew, then about what was clearly presented in the slides, asked to compare the information or to reason. There could be not one right answer to the teacher's question. This encouraged students to actively participate in the lesson and to involve into activities. The students demonstrated information transference and critical thinking abilities when they needed to compare objects and to reason about them, referring to object features, to make conclusions, to explain how they understood the concepts, however, comparatively there were not many such questions. The students freely expressed their opinion, raised themselves thinking questions to the teacher and to their class students, participated in the discussions, which usually they initiated themselves. There was lack of their opinion expression and the heard information argumentation.

In the third form, balance was held between lower and higher-order thinking tasks. The teacher raised a lot of knowledge and understanding questions at the beginning of the lesson, when the students were asked to remember the previous lesson information, also, at the end of the lesson, when it was checked what the students learnt during the lesson. Analysing the new material, higher order thinking questions and tasks were applied, activities were organised – work in pairs, in groups. Such tasks were given, performing which the students consulted each other, searched for arguments, supplemented each other. A lot attention was devoted to the new information finding, transferring their possessed knowledge to new situations. Students were constantly activated giving intriguing questions, hints. The teacher did not reveal new information but allotted such tasks having performed which the students found new knowledge themselves, checked it, comparing with what they already knew. Different groups tried to find out different things, compared different facts. Later, discussing the findings with the class students, shared information and deepened their and other students' understanding. Working frontally, the students joined at the same time different lesson and different topic knowledge, compared it with the analysed lesson material. The students were critically thinking about the information accuracy, preciseness, joined into one wholeness separate information details and on the basis of this made conclusions. At the end of the lesson, a common picture about vertebrates was put together from separate parts. The least in the lesson was allocated to tasks and questions for problem solving. Content information could be related more to the real-life context. Subject content was dominating in the lesson, though world cognition subject is very realistic itself, therefore it is not difficult to find links with the student's surrounding environment. Having related new material with the life context, more tasks and questions could appear for problem solution.

In the fourth form, from the beginning of the world cognition lesson, conditions were formed for the students' higher-order thinking ability development. Students created a thinking map on the lesson topic, in which firstly they marked what they already knew and further filled it in with the new information. The topic, which was discussed in the lesson was rather narrow, covering only one historical event, however, seeking to develop deeper students' understanding about that time events, a wider historical context was included, covering a few centuries till the discussed event. Consequent movement was noticed from knowledge and understanding to the higher-order thinking. Knowledge, understanding and application questions helped to purify and consolidate the information details, then it was critically thought about the same things – the events compared, reasoned about their beginning and ending, considered about different solutions and turnings. A lot attention was devoted to the discussed event narratives, which were presented with the help of information technologies. Information transference questions and tasks helped to join separate narrative facts into one common understanding. There were no questions and tasks oriented into problem solving abilities in the observed lesson, however, the mentioned abilities were developed in this class. This emerged when homework was discussed, which students would account in future. The discussed fourth form world cognition lesson topic was relevant, however, was very distant from this age children surrounding environment. No relationship was sought with today's life, questions and tasks were applied in the discussed period frames.

Conclusions

In the world cognition lessons in all classes, teachers hold the balance between lower and higher-order thinking questions and tasks. In the education process, it is consequently moved from the lower to the higher order of thinking. Knowledge and understanding are applied at the beginning of the lesson, when it is encouraged to remember, what was learnt in the previous lessons, also at the end of the lesson, seeking to consolidate new information. Higher order thinking questions and tasks were usually applied discussing new material. In the observed 1-4 form lessons, all thinking categories emerged: transference, critical thinking, problem solution. Critical thinking tasks and questions were mostly noticed when it was asked to compare information, consider about its certainty and accuracy, to express one's opinion, to ground it with arguments, make conclusions. Quite often teachers applied tasks and questions, when it was necessary to transfer the possessed knowledge to new situations, to join different topic knowledge into one wholeness and to find new things. It was noticed the least of the questions and tasks oriented into problem solving. In the observed lessons, there happened to be one or two such type tasks usually assigned as homework tasks. However, the main difference emerged in the 1-4 forms according to the age groups, implementing the lesson content. In the first-second forms, the teaching content was very related to the real-life context, examples and links were sought with the student's surrounding environment. In the third-fourth forms, the teaching content was more constructive and concrete.

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KEYNOTE SPEAKERS

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Title: CHANGES ALL AROUND US AND WITHIN SCIENCE EDUCATION

Dr. Andris Broks is a Professor Emeritus at the Faculty of Physics, Mathematics and Optometry, University of Latvia in Riga. He completed his PhD in the field of solid state physics and he currently works in the field of physics education and teaches across a wide range of general education topics. His principal research interests today are: systems thinking and systemic approach in physics education, the philosophical and psychological basis of Science education. He has been working on Education Law of Latvia as well as participated in education innovation projects at the national and international level. From 2002 he serves as a Deputy Editor-in-Chief of the Journal of Baltic Science Education and is a member of the Editorial Board of the journal „Problems of Education in the 21st Century".

Dr. **Todar Lakhvich**
Belarusian State Medical University, Republic of Belarus

Title: ONE CHEMISTRY - TWO MEANINGS. SCIENCE AND EDUCATION: COMPARATIVE ANALYSIS OF THE ROLES, PRESENTATION AND APPLICATIONS

Todar Lakhvich is associate professor of Organic Chemistry and now works at Belarusian State Medical University. He has also worked previously at Belarusian State University, University of Konstanz (Germany) and for almost 15 years as the head of the Chemistry department at the Belarusian State Pedagogical University.

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Title: METACOGNITIVE STRATEGIES IN SCIENCE AND TECHNOLOGY EDUCATION: LIMITS AND POSSIBILITIES

Dr. Solange Locatelli graduated in Chemistry from the University of São Paulo (USP), where she also developed her Masters and PhD in Science Teaching. She has worked as a Chemistry teacher in high school and higher education since 1991. Currently, she is working at the Federal University of ABC (since 2016), working as a teacher and researcher. From 2019, she has assumed the position of vice-coordinator of the Postgraduate Program in Teaching and History of Sciences and Mathematics, having participated as a member of this collegiate (2017-2018). She has also been coordinator of the Institutional Scholarship Initiative Program (PIBID), collaborating in the training of future teachers, since 2016. From 2017, he has been a member of the editorial board of the following scientific journals: Natural Science Education (Lithuania), Amazônia - Journal of Education in Science and Mathematics, Chemical Education at Point of View and Brazilian Journal of Science and Mathematics Education. She has been researching in Science / Chemistry Teaching focusing on the aspects of metacognition and neuroscience in teaching-learning. The focus has been on metacognitive strategies, the representational levels of Chemistry, and education for the deaf.

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Title: ENGINEERING PEDAGOGY SCIENCE AS THE CONTEMPORARY BASIS OF EFFECTIVE TEACHING SCIENCE AND TECHNOLOGY

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